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ORIGINAL ARTICLES.

The Kainozoic Igneous Rocks of Kintyre.

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1. INTRODUCTION.

IN a previous paper [1] I have described the igneous rocks of that part of Kintyre contained in Sheet 12 of the 1 in. maps of the Geological Survey of Scotland. The present work deals chiefly with the minor intrusions of the greater part of Kintyre N. of Sheet 12, and contained in Sheets 20, 21, 28, and 29.[2]

By analogy with other parts of Western Scotland and from local evidence the following age-classification of Kintyre igneous rocks is made out :—

Kainozoic (Intrusive).
Permo-Carboniferous (?) (Intrusive).
Carboniferous (Contemporaneous and Intrusive).
Old Red Sandstone (?) (Intrusive).
Pre-Foliation (Intrusive).

The present paper deals with the Kainozoic intrusions.

2. DISTRIBUTION.

(a) In Sheet 12 *dykes* are scarce. At the extreme S. of Kintyre there are two small dykes on the shore at Keil Point. Several small dykes occur to the N., N.E., and E. of Culinlongart, Glen Breackerie.

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[1] *Trans. Geol. Soc. Glasgow*, xviii, i, 1927–8.

[2] For sheet-numbers, see Fig. 1.

An intrusion S.W. of Killypole Loch is probably in the form of a dyke. Small dykes occur on the coast N. and S. of Davarr Island. At Carrick Point and Ardnacross Bay there are three large dykes.

On the western coast of Southern Kintyre small dykes, not shown on the 1 in. map, occur in the neighbourhood of the Mull Lighthouse. Between the Galdrings dykes and the Mull Lighthouse there are occasional dykes to the W. of Largybaan, and to the W. and N.W. of Cnoc Moy.

Besides the above there are several *plugs* of basic igneous rocks at the following localities: N., N.E., and E. of Culinlongart, Homeston, and W. of Achnaglach, Killellan.

Intrusions in the form of *sills* occur at Gart nan Copaig, S.W. of Tirfergus Hill, and along the coast W. of Largybaan.

(*b*) The district included in sheet 20 differs remarkably from the above in possessing many *dykes*. The eastern coast of Kintyre, from Carradale to Cour, is thickly injected by dykes and this belt stretches across Kintyre in a north-westerly direction. Large dykes occur at Carradale, and there are many dykes along the coast at Saddell. A sill-like intrusion at the head of Saddell Glen is not indicated on the 1 in. map.

(*c*) *Dykes* are also abundantly exposed along the eastern coast of Kintyre in sheet 21. In the Memoir of the Geological Survey of Scotland, *The Geology of North Arran, South Bute, and the Cumbraes, with parts of Ayrshire and Kintyre*, it is stated that between the mouths of Skipness and Cloanaig Waters there are seven dykes of the " ordinary type of Tertiary basic dykes of the region ". None of the dykes exceeds 4 feet in width. One, which occurs about 400 yards N.E. of Sgeir na Luinge, is 20 feet across. A group of four dykes varying from 10–20 feet in width occurs near Port Alasdair Ruadh at the margin of the map. Apart from the above, only two small dykes are exposed in inland sections.

(*d*) Small *dykes* are occasionally met with in sheet 28 along the coast of West Loch Tarbert. A large E.–W. dyke crosses West Loch Tarbert at the burn S.W. of Woodhouse, 3½ miles S.W. of Tarbert.

(*e*) Two large E.–W. *dykes* cut the central part of Kintyre contained in sheet 29. Other dykes are represented by one or two small exposures in burns, chiefly near the shores of West Loch Tarbert. A small dyke occurs at the Concrete Pier, Tarbert, and another at Mealdarroch Point. The E.–W. dykes are not dealt with in this paper.

J. B. Hill in the memoir on the Geology of Cowal said that it appears as if the dykes diminish in number as the elevation of the ground surface increases, and he gives examples of districts where the number of dykes is greater on the coast than in inland sections. Unfortunately the superficial deposits in Kintyre make it difficult to test the truth of this statement, but it is my opinion that it holds true in many cases. As an example I may cite the dyke on Mealdarroch Point, Tarbert. This dyke is not shown on the 1 in.

map, but reference will be made to it later. At a short distance above sea-level a foot or so of the dyke at the southern margin has a roof of schists and the remainder of the outcrop can be followed for a few yards. Inland, however, no trace of the dyke has been found.

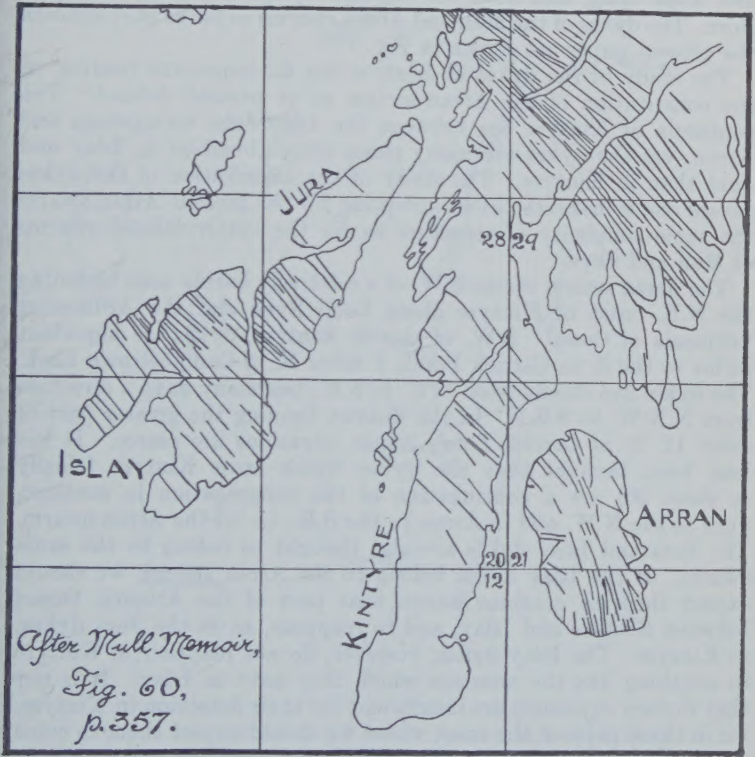

FIG. 1.—Sketch-map showing the Dykes of Kintyre in relation to the Dyke-Swarms of South-Western Scotland. The 1 inch maps of the Geological Survey of Scotland which include parts of Kintyre are indicated.

3. RELATION OF THE KINTYRE DYKES TO THE DYKE-SWARMS OF WESTERN SCOTLAND.

Much has been written in recent years on the Kainozoic dykes of W. Scotland. At present it is generally believed that the dykes occur in three swarms called the Skye, Mull, and Arran swarms. There seems also to be justification for assigning the dykes of the N. of Ireland to a N. Irish swarm.

The Skye swarm has representatives in a stretch of country reaching from Harris and N. Uist through Skye and the mainland to the S.E. as far as the Great Glen Fault. The Mull swarm stretches from S. Uist via Coll, Mull, Lorn, Mid-Argyll, Cowal, and the Firth of Clyde to the N. of England. The Arran swarm, as at present defined, includes the dykes of Colonsay, Islay, Jura, Kintyre, Arran, and Ailsa Craig, and stretches through Ayrshire to Kirkcudbrightshire. The dykes of the Mull and Arran swarms as far as they concern the present paper are shown in Fig. 1.

The study of the dykes of Kintyre has an important bearing on the constitution of the Arran swarm as at present defined. The peninsula of Kintyre lies between the Islay-Jura archipelago and Arran, yet the dykes are many times more abundant in Islay and Jura than in Kintyre. The study of the distribution of the dykes causes one to hesitate before accepting for the present Arran swarm the same simplicity of structure as for the better-defined swarms of Mull and Skye.

The Arran swarm occurs S.W. of a relatively barren zone including the N.E. coast of Kintyre along Loch Fyne and the Ardlamont peninsula of Cowal. S.W. of this in Kintyre, dykes are abundant as far to the S. as Carrick Point, 4 miles N. of Campbeltown Loch. The dykes run chiefly from N.W. to S.E., but many have a direction from N.N.W. to S.S.E. In the district forming the greater part of sheet 12, S. of Carrick Point, minor intrusions are scarce. It has long been thought that the dykes which cross Kintyre (chiefly in sheet 20) are a continuation of the congregation in southern Jura to the N.W. and in Arran to the S.E., i.e. of the Arran swarm. The Jura and Islay dykes are also thought to belong to the same swarm. If the Islay dykes belong to the Arran swarm, we should expect them to continue across that part of the Atlantic Ocean between Kintyre and Islay, and to reappear, as do the Jura dykes, in Kintyre. The Islay dykes, however, do not reappear in Kintyre in anything like the numbers which they have in Islay. It is not that surface exposures are insufficient for their detection in Kintyre, for in those parts of the coast where we should expect them to come ashore, exposures are as a rule sufficiently good for one to decide whether or not a dyke-swarm is present. Dr. Thomas has already called attention to this fact in the Ardnamurchan memoir,[1] and in his address to the British Association (Leeds, 1927).

Occasional dykes are met with in the cliff-sections from Machrihanish southward, but the Islay dykes have practically died out in the interval between the island and Kintyre. This is contrary to what one would expect if Arran is the focus of these dykes. It is true that the dykes representing the continuation of the central Kintyre dykes are more abundant in Arran than in other parts of

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[1] Mem. Geol. Surv. Scotland, *The Geology of Ardnamurchan, North-west Mull, and Coll*, 1930, 61.

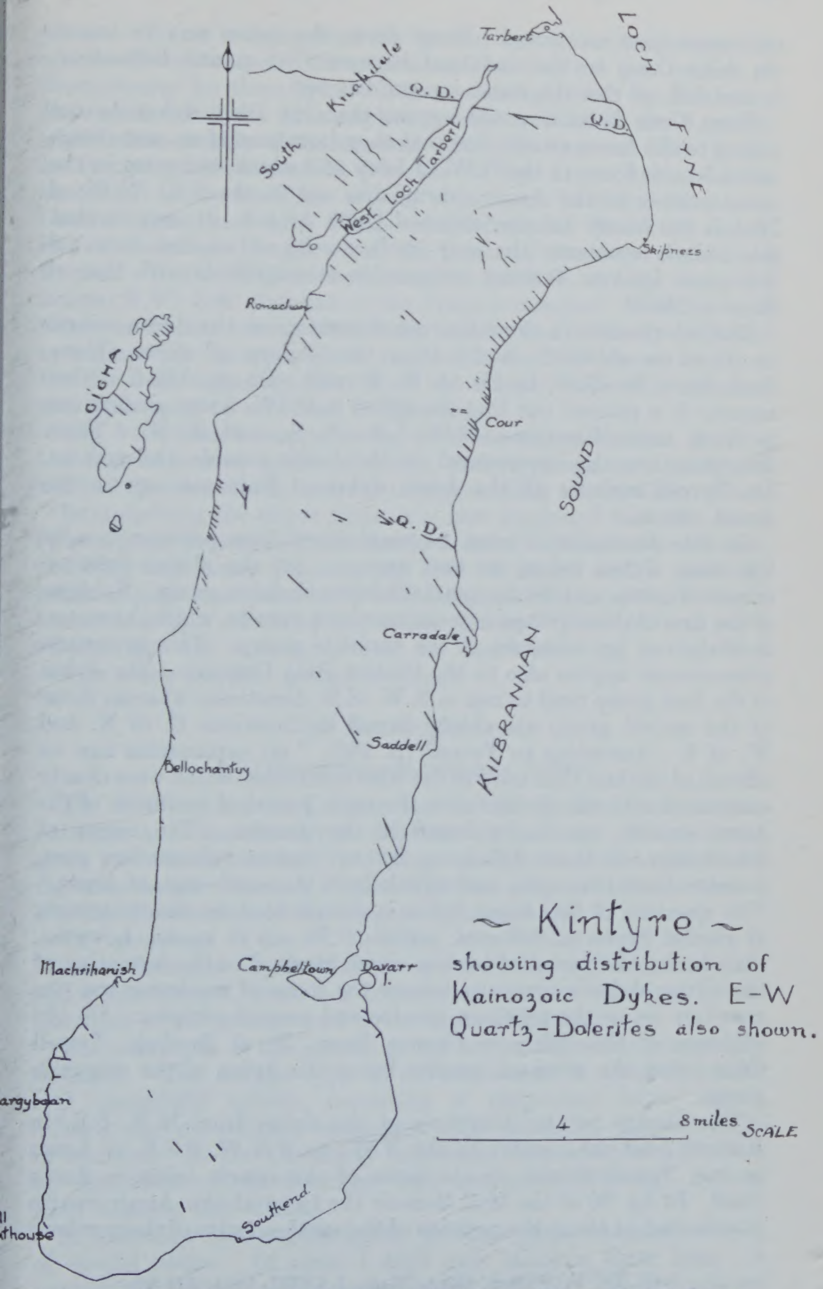

FIG. 2.—Kintyre, showing distribution of Kainozoic dykes. E.-W. Quartz-dolerites also shown.

the course just mentioned. From Arran the dykes may be traced via Ailsa Craig to the mainland between Girvan and Ballantrae. S. and S.E. of this the Arran swarm dies out.

From these facts it would appear that the Islay dykes do not belong to the Arran swarm, but that they form part of an assemblage which has its focus to the N.W. of Islay and which, behaving in the same manner as the Arran swarm, dies out to the S.E. N.W. of Islay is the lonely dolerite island of Dubh Artach. It may be that this island represents the only surface relic of another focus of Kainozoic Igneous Activity comparable in magnitude with that of Skye or Mull.[1]

The information in the following discussion on the Arran swarm in Arran is obtained chiefly from the *Geology of Arran* (Mem. Geol. Surv. Scotland, by Dr. G. W. Tyrrell). On pp. 162–3 of that memoir it is pointed out that the dykes in the N. Arran granite run in three main directions—N.W.–S.E., N.–S., and E.–W. These directions are also represented in the faults outside the granite. Dr. Tyrrell includes all the Arran dykes of Kainozoic age in the Arran swarm.

In this discussion it must be emphasized that petrographically the basic dykes belong to two groups; (*a*) the olivine-dolerite-crinanite group, and (*b*) the quartz-dolerite-tholeiite group. No dyke of the first of these groups cuts the northern granite, which, however, is freely cut by members of the tholeiite group. This important phenomenon applies also to the Central Ring Complex. The dykes of the first group tend to run in N.W.–S.E. directions, whereas those of the second group are chiefly found in directions E. of N. and W. of S. According to Tyrrell (p. 250), " no explanation can be offered of the fact that none of the later crinanites, which were closely associated with the tholeiites in the main period of intrusion of the Arran swarm, are to be found in the granite. The centre of distribution of these dykes, as far as present information goes, seems to lie in the south, and especially in the south-east, of Arran." This question of the Arran dykes is complicated by the recurrence of similar types at different periods. To me it seems, however, that during the period of tension which resulted in the formation of the olivine-dolerite-crinanite swarm the focus of weakness was the reservoir below the northern granite and central complex. On the evidence of the dykes in Cnocan Burn, N. of Brodick, Tyrrell thinks that the northern granite bakes the dykes of the crinanite group.

The change in the directions of the dykes from N.W.–S.E. in Kintyre (and the country to the N.W.) to N.N.W.–S.S.E. in Arran is due, Tyrrell thinks, to the focus of the swarm being in Arran itself. In fig. 60 of the Mull Memoir the focus of the Arran swarm is indicated at about the position of the southern edge of the northern granite. To me it seems that the igneous centres in Arran were the centres of weakness for the crinanites, and they are now centres of discontinuity for these dykes. It is also thought that the centre for the remainder of the Arran dykes, mostly crowded in the S. of the island, lies outside of Arran, and probably near to Ailsa Craig. In this way the almost N.–S. trend of the Arran dykes can be accounted for, as the three centres of intrusive activity—N. Arran, Central Arran, and Ailsa Craig—would form an almost N. and S. line of weakness through which the tensional fractures would tend to pass. To the N.W. of Arran and to the S.E. of Ailsa Craig the normal N.W.–S.E. direction of the dykes is resumed. Such a line of weakness as that joining these three centres was evidently sufficient to attract the fractures which resulted in the Mull swarm in Bute, for the Bute dykes are bent from the normal N.W.–S.E. trend of the Mullswarm to a N. and S. direction.

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[1] Cf. Dr. F. Walker, **Geol. Mag., LXVIII, 1931, 318–20.**

Fig. 3 is a sketch-map, after fig. 34 of the Arran Memoir, showing the distribution of dykes in Arran, and it brings out clearly the marked increase in the number of dykes along the southern coast.

Summarizing the above facts, it is here suggested that the Arran swarm, as at present defined, should be subdivided into two swarms, the Islay and Arran swarms, and that the Arran swarm probably contains more than one swarm with different centres (*a*) the N. Arran centre and (*b*) a centre off the southern coast. Without here going further into the subject, it may be mentioned that in the Irish swarm there are also several swarms.

(4) PETROGRAPHY.

(a) *Olivine-dolerite-crinanite Group.*

The N.W. dykes of Kintyre are for the greater part olivine-dolerites and analcite-olivine-dolerites (crinanites). The rocks of these two classes can best be distinguished from one another under the microscope. There is little doubt that they are closely related. For the distribution of the Kintyre dykes see Fig. 2.

The petrology of the N.W. dykes is now fairly well known in Western Scotland. In the Memoir on the *Geology of Jura, Knapdale, and North Kintyre*, there is a description of rocks which are a continuation of the greater part of the rocks in Kintyre.

The characters of the present group are on the whole remarkably constant. The normal type of olivine-dolerite is non-porphyritic and beautifully ophitic, consisting of plagioclase laths, augite, olivine, and subordinate magnetite. The crinanites carry analcite in addition. In the University collection there are over 130 slices of Kainozoic olivine-dolerites and crinanites collected by me from Kintyre and Gigha.

In addition to the normal dykes, there are some which are worthy of special notice. Of these I shall only mention three here. A porphyritic olivine-dolerite occurs in Allt Caillich. The groundmass of the rock is a fine- to medium-grained ophitic dolerite, and embedded in this are numerous large laths of plagioclase. Along the cleavages of the phenocrysts are abundant thin stumpy or curiously shaped pieces of augite, which are in optical continuity sometimes with one another and sometimes with the augite of the groundmass. The slide of the dyke between the porphyrite intrusions on the road to the Mull Lighthouse contains many large rounded vesicles of brown and brownish green material, around which the felspars and augite are arranged with good ocellar structure. The remarkable feature of the rock is that a great many of the interspaces are filled with material similar to that of the vesicles, the origin of which is unknown (delessite, chlorite ?). Similar material occurs in the dyke at Closeburn. In this dyke there is practically no fresh olivine.

The crinanites can only be distinguished from the olivine-dolerites above described under the microscope. Even in thin section the amount of analcite in some of the crinanites is so small that they might be grouped with the olivine-dolerites.

The differences in the plagioclase, augite, and olivine in the rocks of the two groups is slight. The augite as a rule seems to be darker in colour in the crinanites than in the olivine-dolerites. In the crinanite dyke at the eastern end of Carskey Bay some plates of augite are half purple and half green in colour. The crinanites usually contain abundant zeolites. Large skeletal crystals of magnetite are common in the dyke at the ruins N.E. of Deucheran Mor in Carradale Glen. In the Cour Island dyke there is a large plate of normal purple augite, but several smaller plates of the same mineral have a decided green colour, and are associated with a green amphibole (?). The analcite, which fills the interspaces, is usually recognized by its somewhat mottled appearance in ordinary light. It often shows a brownish colour, and between crossed nicols it is isotropic in most sections, though some parts show low double refraction. Sometimes the analcite is very turbid, and stands out as a dark grey mass in sharp contrast to the clear laths of plagioclase. Material, which in ordinary light looks identical with the analcite, appears between crossed nicols as radial fibres of low, doubly refracting material. The slide of the dyke at Port an Dunain, Sunadale, is exceptionally rich in these spherulitic aggregates. The same is true of another from West Loch Tarbert. Analcite is very abundant in some slides.

In the slide of the crinanite forming the third dyke N. of A'Chleit there are two rocks with no chilled or even sharp margin separating them. In one, which appears lighter in colour, the olivine is typically fresh, except along fractures, where it has been changed into pale green serpentine. In the other the olivine is practically all decomposed into green and brown secondary products. Both rocks are crinanite.

Since the olivine-dolerites and crinanites are for the most part parallel it is seldom that they are found cutting one another. In

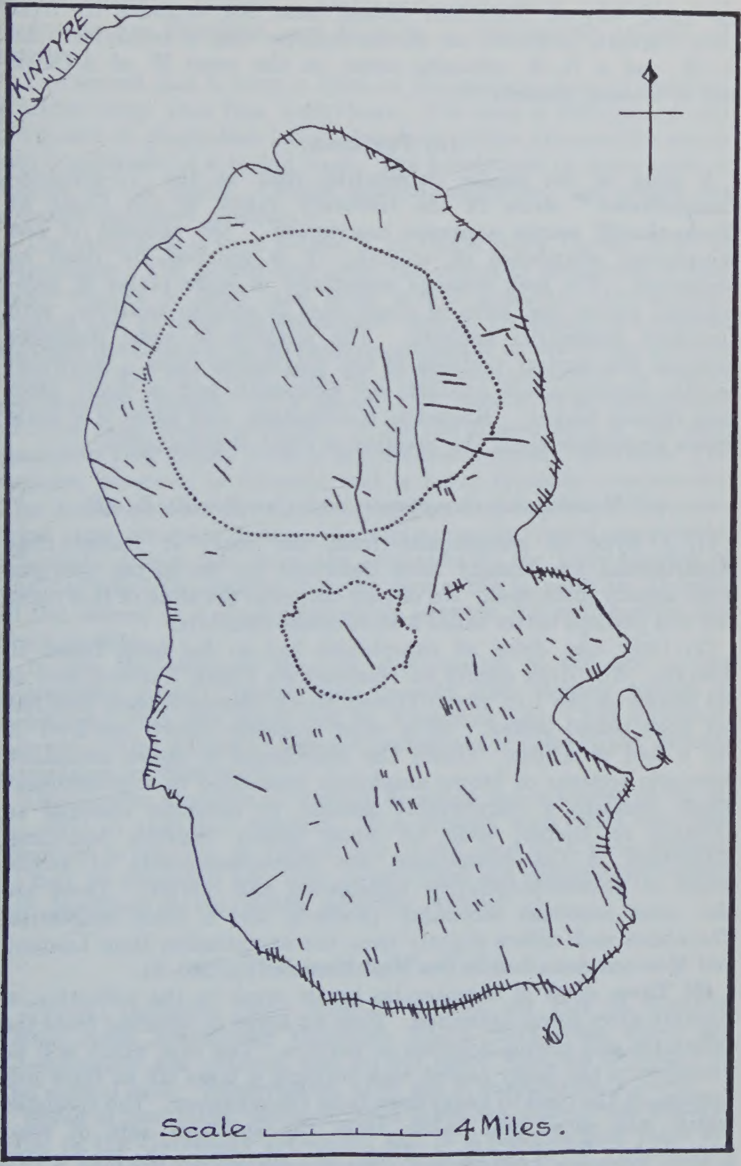

FIG. 3.—Arran (with part of Kintyre) showing the distribution of Kainozoic dykes. After fig. 34 of Arran Memoir. The dotted lines indicate the outcrops of the Northern Granite and Central Ring Complex. Note the great abundance of dykes along the southern coast.

the small bay at Ronachan House, near the entrance to West Loch Tarbert, however, an olivine-dolerite cuts a crinanite. An E.–W. and a N.–S. crinanite occur on the coast N. of A'Chleit and at Crosaig respectively.

(b) *Teschenite.*

A slide of the coarse gabbro-like rock at the "5-miles-to-Campbeltown" stone in the tributary valley of the Conie at Glecknahavill merits separate description. On account of the exceptional abundance of analcite, it is grouped by itself as teschenite. The rock consists essentially of large plates of pale-coloured augite and laths of plagioclase in ophitic relations, with abundant interstitial analcite. The analcite in some instances occupies the central portions of the plagioclase laths. Brownish zeolitic decomposition products are abundant, and in many cases they replace felspar. Magnetite is abundant, and there is a little brown amphibole along the margins of some of the augites.

(c) *Monchiquite, Camptonite, and Camptonitic Basalt.*

(1) A dyke of monchiquite from the coast at Losset near Machrihanish has already been described by me in the previous work already mentioned. No olivine occurs in the slide of this rock, and it is perhaps better called a hornblende-fourchite.

(2) Only one dyke of camptonite has so far been found in Kintyre. The dyke occurs on Mealdarroch Point, Tarbert, and is not shown on the 1 in. map. It cuts Beinn Bheula Schists, and has not been traced inland. At a short distance above sea-level it has a roof of schists. Under the microscope it shows abundant prismatic sections of brown amphibole embedded in a groundmass which contains a considerable amount of isotropic material in addition to felspar, some of which shows multiple twinning. Embedded in the groundmass are microphenocrysts of augite (often in glomeroporphyritic aggregates) and olivine. There are also some brownish secondary products and a little magnetite. The above rock differs slightly from the camptonites from Lismore and Morvern described in the Mull Memoir (pp. 380–2).

(3) Three slices of camptonitic basalt occur in the collection of Kintyre slices being examined. They all agree in differing from the crinanites and olivine-dolerites in texture. The first which will be described is the fairly coarse rock forming a large sill at Gart nan Copaig, on the road to Largybaan from Glenahantuy. The specimen which was sliced was taken from the southern side of road immediately W. of the farm. Under the microscope the rock is seen to be somewhat coarser-grained than the average crinanite above described, and differs from the crinanites in the idiomorphism of the augite, which occurs in well-formed eight-sided crystals with good cleavage. The plagioclase occurs in a plexus of laths (often zoned)

with interstitial analcite. Olivine decomposition products and magnetite are abundant, and there is a considerable amount of biotite.

The second slice is from a dyke on the western shore of southern Kintyre below Dun Ban, Largybaan. The rock is fine-grained and composed of plagioclase laths, abundant purple idiomorphic augite and hornblende in a turbid base. The hornblende in many cases is formed on the augite. Calcite, apatite, magnetite, and sphene are common accessory minerals.

The third slide is from a dyke E. of Uamh Ropa, Cireon, N.W. of Largybaan. The slice differs from the others in possessing several large vesicles of fresh (and some turbid) analcite. Idiomorphic augites and olivines are abundant. Brown amphibole is scattered through the slide and is particularly abundant in one or two sections composed for the most part of amphibole embedded in turbid decomposed analcite. As a general rule these clots of decomposed analcite carry augite crystals. To me the greater part of this slide resembles very closely some of the crinanites already described. The texture, however, is different and is fairly typically camptonitic. The darker patches of amphibole, augite, and analcite differ somewhat from the mass of the slide, and are more typical camptonite. The slide differs, too, from the crinanites in the large amount of analcite which it contains, but the slice seems to point (as do some of the others) to a close relationship between the camptonites and the crinanites.

In the Mull Memoir there is a discussion of the age of the camptonite group. It has been thought with varying degrees of confidence that the rocks are of Kainozoic age. The evidence, however, so far published does not permit one to come to any definite conclusion on this point.

Camptonite localities in western Scotland are indicated in fig. 60 (p. 357) of the Mull Memoir. The present work adds two new localities to this, viz. at Tarbert and on the coast S. of Machrihanish. It may be remarked here that camptonites and camptonitic basalts are described in the North Ayrshire Memoir.

(d) *Tholeiites and Leidleites.*

Typical tholeiites (Mull Memoir, p. 280) are rare in Kintyre. Those rocks resembling tholeiites which have been sliced are exceptionally fine grained, and do not agree with the definition of the normal rock. Nevertheless, they are of remarkable interest.

Slices of two fairly representative tholeiites dykes from Kintyre exist in the University collection, and it is possible that there are others which have not been sliced. The existing slices are from a dyke on the shore of West Loch Tarbert, past Rhu Island, and the other from Dippen, Carradale. Under the microscope the slices of these two dykes resemble one another very closely. As already mentioned, the rocks are fine-grained and consist of a glassy groundmass, in which are embedded tiny rectangular crystals of plagioclase and some decomposition products possibly representing original augite or olivine or both. There are occasional large microphenocrysts of plagioclase. The Dippen rock is on the whole clear, but the groundmass is richly charged with minute specks of black iron oxide. The microphenocrysts of plagioclase often have a parallel alignment. There are relics of olivine and some serpentine.

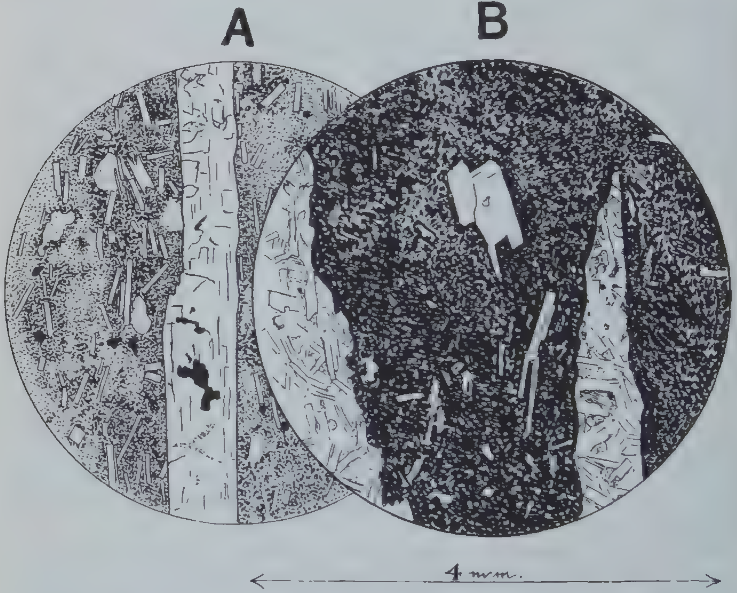

Fig. 4.—A. Leidleite. Dyke (1 yd. in width) intruded into 6 yds. dolerite S. of Sgeir Bheathaig Eascart, E. coast of Kintyre. The large crystal crossing the section is of greenish-yellow augite. The small laths are of plagioclase and the groundmass is devitrified glass with patches of clear brown glass (more sparsely dotted). B. Dippen Tholeiite showing lenticular inclusion of crinanite and junction with crinanite to left.

In another slide of the rock there is a portion of the field, which is composed of typical crinanite, and the contact of the two rocks is very sharp. At the contact the tholeiite is chilled to a dense black colour. Small phenocrysts of augite in the tholeiite seem to have been derived from the crinanite. Enclosed within the tholeiite is a lens-shaped section of the crinanite (Fig. 4B). In some parts, instead of the glassy rock stopping sharply at the margin of the crinanite, it seems to have diffused much of its iron oxide through the latter, giving a very confused mass of black material with lighter coloured patches, and patches of doleritic material. The evidence from the slides of the Dippen rock points to the crinanites being older than the tholeiites. In Arran, Tyrrell has found much evidence to show that the dykes of the tholeiite group cut those of the olivine-dolerite-crinanite group.

In addition to the above, there are two slices of a small dyke resembling the leidleites. They are from a dyke at Sgeir Bheathaig, on the eastern shore of northern Kintyre at Eascairt. The dyke is only one yard in width, and is intruded into a six-foot dolerite. The slices are made up chiefly of turbid devitrified glass, with numerous irregular patches of fresh yellow glass. There are abundant small laths of plagioclase arranged with good flow structure, and some larger mechanically zoned felspars. Augite occurs in one narrow plate, pleochroic from green to yellow, and in occasional small crystals. Magnetite is scattered irregularly through the sections, and calcite is fairly abundant (Fig. 4A). A one-foot dyke in the Breacherie Water, N.W. of Glenahantuy, belongs to this group rather than to any of the others. In a hand-specimen the rock seems very decomposed, and is banded with dark purple and greyish bands, in which are embedded small rectangular and rhomboidal sections of light-coloured felspar. Under the microscope the groundmass is very fine-grained, mottled in colour, and rich in small specks of iron oxide. Embedded in this material are numerous evenly distributed rectangular laths of altered plagioclase. Some bands are dense brown in colour.

In conclusion I wish to make acknowledgement to Professor Bailey for his generous help during the development of this work, and for his constructive criticisms of the original manuscript.

On the Occurrence of Custerite and Monticellite in Metamorphosed Limestone from the Carlingford District, Co. Louth, Ireland.

By G. D. Osborne.

WHILE recently investigating the contact metamorphism of the scattered Carboniferous limestone outcrops in the neighbourhood of Carlingford and Barnavave, Co. Louth, some striking rocks containing large crystals of mica and calcite, and small crystals of pyroxene and spinel were found by the writer at the south-east end of Barnavave Mountain. During the microscopic examination of this material the minerals in question were detected, and it is the purpose of this note to place this interesting occurrence on record.

The actual specimens containing the custerite and monticellite vary greatly from place to place in texture and mineral constitution. In all the custerite-bearing rocks, vesuvianite is this mineral's most intimate associate, while phlogopite, apatite, calcite, and monticellite come next in importance in this respect. The spinel (pleonaste) of these rocks is never in contact with or very close to the custerite, but rather is embedded in the phlogopite plates.

The custerite is grey in colour, and often difficult to distinguish from the associated minerals. It occurs mostly in cleaved xenoblastic masses up to 9 mm. in diameter, which enclose crystals of vesuvianite (now much altered), and small units of diopside, phlogopite, wollastonite, and edenite. In other cases in custerite-vesuvianite-calcite assemblages the first-named is found as extremely ragged aggregates filling in the spaces between the other two minerals. In thin section the mineral is colourless, but thick sections show patches of palest-brown colour, possibly due to ultra-microscopic inclusions. Sections in the (100) : (010) zone show well-developed polysynthetic twinning on (001) which, however, is sometimes capricious in its occurrence in any one grain. The (001) cleavage is fairly prominent, but only traces of the prismatic (110) cleavage are seen. Sections parallel to (010) give the maximum extinction angle ($Y \wedge a$) of $6\frac{1}{2}°$. The mineral is optically positive, with axial plane normal to (010), and Z nearly perpendicular to the basal pinacoid; dispersion, $\rho > v$, is moderately strong. The optic axial angle was measured on the microscope, using the Becke-Collingridge construction, $2V$ being 63° approximately. The R. I.s have been determined with immersion-liquids as follows: $\alpha = 1{\cdot}590$, $\beta = 1{\cdot}596$, $\gamma = 1{\cdot}601$; $\varDelta = {\cdot}011$. These optical properties are in agreement with those of the custerite from Idaho and Crestmore, and the very distinctive features of the mineral leave no doubt whatever as to its identity.

The monticellite occurs in mostly irregular, but occasionally subidioblastic grains up to 5 mm. in diameter. Under the microscope it shows characteristic cracking but no cleavage. Using immersion-methods the R. I.s were found to be $\alpha = 1{\cdot}652$, $\gamma = 1{\cdot}669$; $\varDelta = {\cdot}017$. The mineral is negative and interference-figures indicate that $2V$ is fairly large. A microchemical test established very definitely the presence of calcium.

Custerite has been described only from Custer, Co., Idaho,[1] and Crestmore, California,[2] and in the latter case the paragenesis is much the same as with the Barnavave example. Apart from the occurrence of these uncommon minerals the Barnavave region is of further interest because of the development, in close association, of typical calc-silicate and calc-magnesium-silicate rocks, together with some remarkable contaminated igneous rocks rich in wollastonite, hedenbergite, and andradite. A description of these interesting assemblages is now being prepared.

DEPT. OF MINERALOGY AND PETROLOGY,
CAMBRIDGE.

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[1] Umpleby, J. B., Schaller, W. T., and Larsen, E. S., *Amer. Jour. Sci.*, iv, xxxvi, 1913, 385–94.

[2] Tilley, C. E., GEOL. MAG., LXV, 1928, 371.

On the Volcanic Zebayir Islands, Red Sea.

By W. A. Macfadyen, M.C., M.A., Ph.D.

(PLATE I.)

THE published amount of precise geological information concerning the relatively recent volcanic islands in the southern part of the Red Sea is remarkably small, being restricted, to the writer's knowledge, to a single paper on Perim Island (1)[1]; even in this case the visit and the collection of specimens were made by one who was apparently not a geologist.

Although the islands lie practically on the main steamship route, they are actually by no means easy of access. Except at Perim Island, where there is a small European community, the only steamer calling is the relief ship which visits the lighthouses on three of them—Jebel Teir, Centre Peak in the Zebayir group, and Abu Ail in the Jebel Zukkur Islands. A visit, therefore, requires a considerable expedition, and on account of the paucity of sheltered anchorages is not altogether a simple matter, since landing is not infrequently impossible owing to rough weather.

In the winter of 1926–7 the writer had a sea-going motor ship at his disposal for the purpose of a geological examination of the Farsan Islands for the Red Sea Petroleum Company. To get such evidence as was possible of the general regional geology, often a matter of some difficulty in this area owing to political exigencies, a landing was made on Jebel Zebayir Island on 7th January, 1927, and half a day was spent exploring it.

The Zebayir group, shown on the accompanying map, comprises ten islands with associated rocks and shoals, extending over 25 km. from NNW. to SSE. The largest island is Jebel Zebayir, 6 km. long and 3.5 km. wide, on which is the highest point of the group, at an altitude of 224 m. The islands rise steeply from a relatively small and irregular marine bank, elongated in the Red Sea trend, and sited in the deepest part of the Red Sea trough in this latitude. They are surrounded by a sea of about 450 m. depth, which some 17 km. to the east and 30 km. to the west shoals rapidly to a depth of 60 to 70 m.

Time did not allow an extensive examination. At the landing place on the north-west corner of the island the country rock proved to be a black vesicular basalt. A traverse inland proved very rough going, but eventually a volcanic cone was reached. After exploring two vents at the base the main cone, point 162 m., was climbed. This was exceedingly steep, the angle of rest of the material being apparently near that of Vesuvius, the only active volcano visited by the writer. At the top the perfect crater rim was not more than about 200 metres in diameter; it was knife-edged, and sloped equally steeply towards the vent as away from it. The cone was composed of scoriae, with a plentiful sprinkling of volcanic bombs

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[1] Figures in parentheses refer to References at end of article.

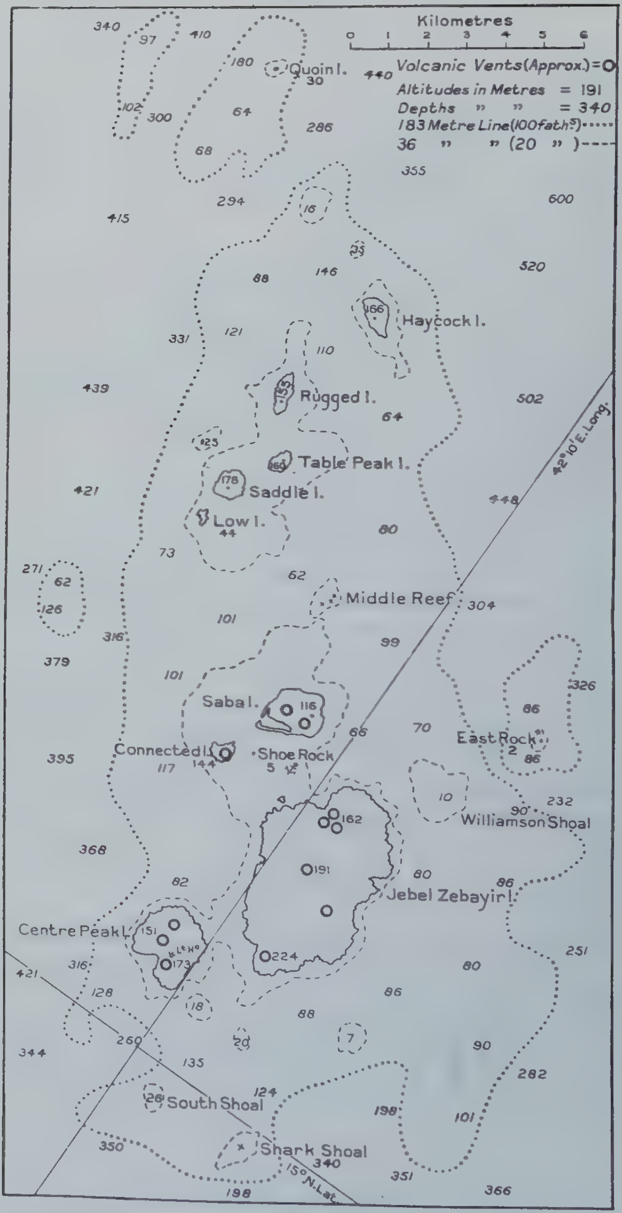
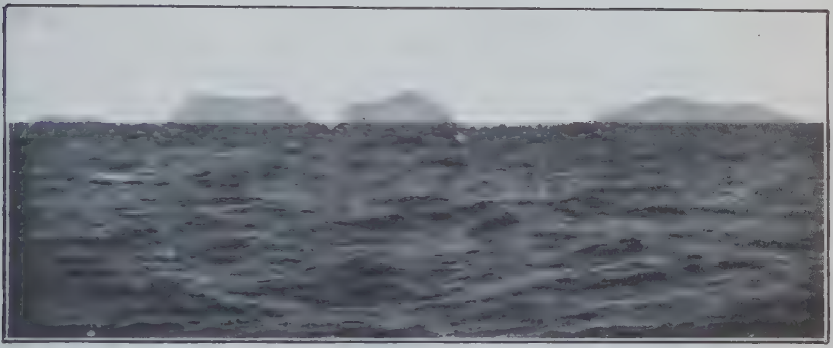
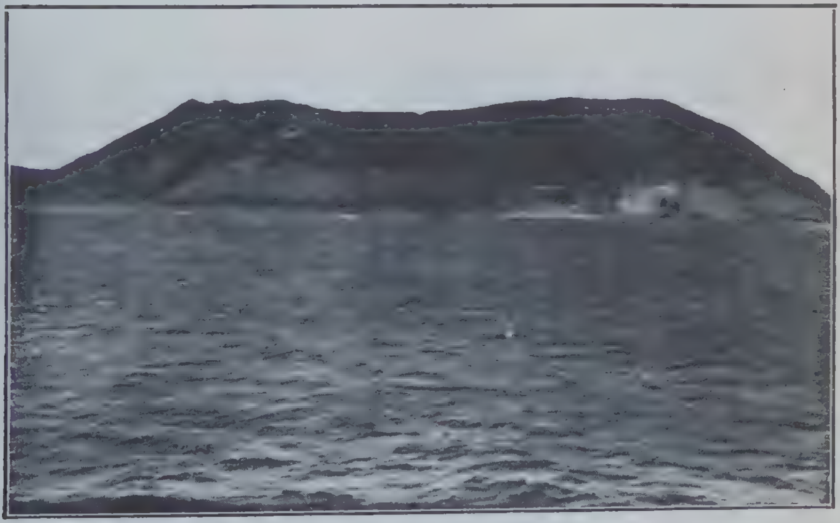


FIG. 1.—The Zebayir Islands. After Admiralty Chart No. 453.





Volcanic Cone on Saba I.

ZEBAYIR ISLANDS.

[*To face p.* 64.

and a very minor quantity of solid lava. The colour of the material was dominantly black, but with a sprinkling of red and a little brown and yellow. At two places on the rim it appeared to have been altered by emanating vapours, the resulting colour being buff, and at a distance suggestive of sulphur. A closer examination showed that it was not; no trace of free sulphur was, in fact, recognized on the island.

From the crest of the rim a fine view was obtained over the whole of the group. On Jebel Zebayir Island itself were counted seven volcanic vents; three cones, including that climbed, were of not dissimilar size, one was a small independent cone, and three were vents parasitic on the larger cones. All were of the same explosive type. To the south lay Centre Peak Island, capped by the lighthouse; three cones of the same type were visible on it. On Saba Island, north of the anchorage, were seen two cones, one of medium and one of small size, as judged by the standard of the one climbed; only the larger is seen in the photograph taken from the ship. On Connected Island, west of the anchorage, was a single small crater. A total of thirteen volcanic cones and vents of varying size was, therefore, counted from the single point of vantage described, and there is no doubt that more would be proved were the islands to be examined systematically.[1]

Further away to the NNW. five islands were visible, Quoin Island not being seen. The writer has a note that each is probably a crater, but he does not now think it was possible to distinguish definite craters at that distance. The second photograph, taken from the east at a range of some 6 km., shows the steepness of their coasts, and suggests marine erosion of soft material. There seems no doubt that the whole group is purely volcanic.

AGE OF THE VULCANICITY.

The old barrier between the Indian Ocean and the Red Sea trough seems to have been situated about the locality of Perim Island. The incursion of the Indian Ocean took place about the Lower or Middle Pliocene (2), and it seems probable that the late vulcanicity of the region may be to some extent at least correlated with the breakdown of this barrier. Blanford (3) has named these late volcanics the Aden Series, but its date certainly varied from place to place. The volcanoes of Aden in Arabia and Elmis in British Somaliland, together with the associated basalt flows in the latter country, are well dissected by erosion: their borders are overlain by raised beaches, which have been examined in both cases by the writer. Raised beaches have also been described overlying the similar lavas of Jibuti (4) and Perim (1). Nevertheless, at the present day active volcanoes attributable to the same series are known from Eritrea (5), (6). So far as the writer observed, there were no raised beaches on the Zebayir Islands, though this requires confirmation. The *Red Sea Pilot* (7th ed., 1921, pp. 117–19) states that Saba Island is fringed by a coral reef extending to the south-west. The material of which the cinder cones are built is so easily eroded that they could not have remained for long, geologically speaking, in the condition in which they are found to-day. The rainfall is small, i.e. as judged from that in the Farsan Islands a little to the north, but it is by no means negligible. The vulcanicity of the Zebayir Islands thus appears to be post-raised beach.

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[1] Only the small scale Admiralty chart was available at the time of the visit. The vents have been plotted recently on the large scale chart from which the accompanying map is reduced; the positions shown are therefore only approximate.

Lamare (7), who reviews the available information, considers that the alleged records of activity of the southern Red Sea volcanoes between about 1824 and 1838, or even later, are untrustworthy. He notes the existence of " émissions fumerolliennes " on Jebel Teir (44 km. NNW. of Quoin Island), though he does not quote a remark by the Hydrographer to the Admiralty writing on the survey of that island in 1882, which runs as follows (8) : " Some activity was going on in this volcanic island, as hot vapour was observed rising from small fissures and cracks, and sulphur was found at its summit." This, taken with the doubted older records and the evidence of the Zebayir cones, suggests that if these volcanoes are definitely extinct, as they appear to be, then they have only recently become so. The more advanced erosion of the steeply cliffed islands in the north of the group, and of Jebel Teir, may indicate that they are somewhat older than the perfect cones in the south of the Zebayir group.

Hand specimens and slides of the rocks collected are preserved in the Sedgwick Museum, Cambridge.

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(2) Cox, L. R., *Proc. Malac. Soc.*, 1929, xviii, 173 ; and Geol. Mag., 1931, 3.
(3) Blanford, W. T., *The Geology and Zoology of Abyssinia*, 1870, 8vo, London, 190–3.
(4) Dreyfuss, M., in Teilhard de Chardin et al., *Mém. Soc. Géol. France*, 1930, N.S., vi, Mém. 14, 86.
(5) Dainelli, G., and Marinelli, O., *Riv. Geogr. Ital.*, 1906, xiii, 261–70 ; and 1907, xiv, 16–26 ; and also 1912, *Risultati scientifici di un viaggio nella Colonia Eritrea*, Cap. 4, " I vulcani della regione costiera." Pubblic. R. Ist. Stud. Sup. Firenze (Sez. filosof. e filolog.) ; [separate publication, xxiii + 601, *non vidi*].
(6) Nesbitt, L. M., *Geogr. Journ.*, 1930, lxxvi, 545–53.
(7) Lamare, P., in Teilhard de Chardin et al., loc. cit., 34–6.
(8) Evans, F. J. O., *Geogr. Journ.*, 1883, v, 595.

Note on the Petrology by Dr. A. Harker, F.R.S.

The specimens are all of basaltic lava, dark grey to black in colour, of texture ranging from compact to scoriaceous, and mostly without conspicuous phenocrysts.

The chief constituent minerals, as seen in thin slices, are augite and plagioclase felspar. The augite is partly in idiomorphic phenocrysts, about 0·25 to 0·5 mm. in diameter, and of pale green to light yellow-brown colour in section. There are sometimes a few small crystals of pale enstatite. In the commonest type of rock grains of olivine are only sparingly represented. There are some scattered felspar crystals of stout shape, 1·5 to 4 mm. in diameter, often honeycombed with glass-inclusions. The dominant felspar, however, gives lath-shaped sections, showing close albite-lamellation and sometimes Carlsbad and pericline twinning in addition. The largest, about 0·5 mm. long, impart something of a microporphyritic appearance, but in fact the crystals range from this size down to fine needles. In symmetrically cut sections the extinction-angles do not exceed 28 degrees, indicating an acid labradorite. The general mass of the rock is composed largely of minute augite-granules, the aforesaid slender felspar needles, abundant magnetite with imperfect and skeletal shapes, and a variable amount of light brown glass.

One highly vesicular specimen differs from the foregoing description in containing relatively abundant olivine, in conspicuous yellow grains, 4 or 5 mm. in diameter. In this variety the larger augites and felspars are lacking, and the glassy residue bulks more largely.

A Teschenite from Rokkutsu near Taihoku, Taiwan (Formosa).

By Takeshi Ichimura (Assistant Professor of Geology of the Taihoku Imperial University, Japan).

It is noteworthy that some analcite-bearing diabase has already been collected by Mr. Y. Deguchi[1] from the Pescadoles Islands and the distribution of the same kind of rock was also noticed by Dr. B. Kotō in the Taihoku district many years ago. Little is known of the occurrence of alkaline rocks in Formosa, for the investigation of these rocks has not been carried out by any geologist. When the writer moved to Formosa, his attention was especially attracted to these rocks, both petrologically and geologically. The work was begun three years ago when he first found very interesting specimens of analcite-bearing rocks at Rokkutsu and published some brief notes[2] thereupon. The present paper embodies further study of analcite-bearing rocks from Rokkutsu.

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[1] Y. Deguchi, *Geological Report on the Pescadoles* (in Japanese), p. 37.

[2] T. Ichimura, "Alkaline Rocks of Formosa" (in Japanese), *Jour. Geog.*, xli (1929), No. 483, pp. 285–9. T. Ichimura, "Brief Notes on the Alkaline Rocks of Taiwan," *Trans. Nat. Hist. Soc. Formosa*, xix, No. 103 (1929), pp. 376–81.

Rokkutsu is a small village situated near the boundary between Shichisei-gun and Bunzan-gun about 6 kilometers to the north from Shiodome Station. The exposure was found along the watershed between Tōshiryō and Kōkaryō with extension north-east to south-west and concave side north-westward. It passes close to a small temple Kōmyōji, partly building up a very steep slope in its northern half. The northern side of this exposure is the highly cliffed valley of Kōkitsukō, while the opposite slope is more gentle toward Rokkutsu. The highest point of the exposure is about 450 meters above sea-level.

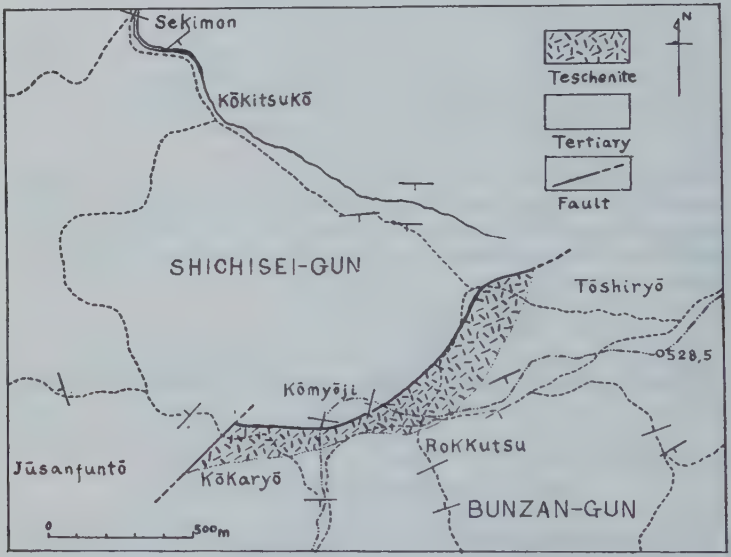

Fig. 1.—Geological map of Rokkutsu and Vicinity.

It is a laccolith or sill injected between alternating beds of shale and sandstone which probably belong to the Miocene. The exposure is traceable about 1400 meters along its length and for 150 meters in the broadest part. The boulders derived from this igneous body are widely scattered on both sides, and the boundary of the sediments and intrusive mass is thus sometimes obscure. The northern and eastern sides form abrupt contacts with gently inclined sandstone and shale beds, being cut by two faults, while it is covered by a light grey sandstone southward. The upper sandstone is partly interstratified with thin beds of grey shale and mostly shows a steep inclination southward, gradually passing into the thick shale zone. No further exposure of the same kind of rock is seen in this neighbourhood, although the writer found some olivine-basalt at Sekimon and also on the opposite slope of the small village called Jūsanfuntō.

The teschenite here is a compact and hard rock with a dark grey colour and somewhat mottled appearance. There are several textural varieties gradually changing from fine to coarse. Some of them pass into a common diabase. Most of the specimens, as a result of varying degrees of exposure, are somewhat weathered, always showing a light brownish grey colour on the surface.

Under the microscope four varieties with somewhat different mineral composition may be distinguished. The first type is composed of oligoclase, andesine, labradorite, aegirine, aegirine-augite, titaniferous augite, analcite, apatite, biotite, magnetite, nontronite, titanite, chlorite, and sericite. It is the most common variety found at Rokkutsu and Kōkaryō.

The second type is a little coarser than the above and belongs to its local facies, showing very limited distribution at Rokkutsu. This type differs mineralogically in the frequent occurrence of barkevikite.

The third type is characterized by the absence of aegirine, aegirine-augite, titaniferous augite, and barkevikite, but contains abundant calcite and chlorite. It is also the common type collected from Kōkaryō.

The fourth type from Tōshiryō lacks biotite and contains natrolite, but in other respects is similar to the third type. The most characteristic feature of these rocks is the entire absence of olivine both as phenocrysts and in the ground-mass. The writer believes, however, that this results from the complete weathering of olivine to other secondary minerals. The rocks always show the coarsely intersertal or ophitic texture common to diabase.

Among various constituents the most predominant mineral is plagioclase. Various species ranging from oligoclase to labradorite are present. Andesine and labradorite mostly take a lath-shaped habit, with twinning after the Carlsbad or albite laws. Both varieties often occur together, with a tendency to be more basic toward the interior. The indices of refraction are $n_1 = 1{\cdot}546\text{–}1{\cdot}557$, $n_2 = 1{\cdot}552\text{–}1{\cdot}562$ on (010). Some crystals are sporadically replaced by analcite, often associated with minute crystals of aegirine and aegirine-augite. Zeolitization and chloritization usually begin along cleavages or cracks. Oligoclase occurs partly as lath-shaped crystals, showing straight or nearly straight extinction, and partly fills up the interstices of the above-mentioned varieties. The index of refraction is $n_2 = 1{\cdot}543$ on (001) and the mineral is optically positive. It is also observed that andesine or labradorite is frequently surrounded by a narrow rim of oligoclase. This undoubtedly proves that the crystallization of oligoclase was later than andesine or labradorite. The felspars enclose magnetite, biotite, and apatite.

Titaniferous augite is abundant in some specimens from Rokkutsu and Kōkaryō. The crystals are always anhedral and often occur as phenocrysts; 5 mm. is the maximum length. The mineral shows a faint pleochroism, viz., X = light purplish brown, Y = light yellow or light yellowish brown, Z = light brownish purple. Absorption: $Z>X>Y$. It is optically positive and the extinction angle, $Z \wedge c$, is about 40°. It commonly has a distinctive cleavage parallel to (110) and twins on (010). The zonal structure indicates a change of titanium content during crystallization. The large crystals sometimes pass into aegirine and aegirine-augite along their margins and rarely in their interiors.

The occurrence of aegirine and aegirine-augite is very common in the specimens from Rokkutsu and Kōkaryō, often in association with analcite. Besides the transition from titaniferous augite, they occur independently as minute anhedral crystals, the maximum length being 0·14 mm. in aegirine and 0·5 mm. in aegirine-augite respectively. Aegirine is characterized by the following pleochroism: X = bluish green, Y = light green, Z = yellowish brown or brownish yellow. The absorption is $X>Y>Z$ and the mineral is optically negative. It has an extinction angle, $X \wedge c$, of 3° and shows brilliant interference colours. Aegirine-augite usually shows a short prismatic habit, but it is long prismatic in the specimens from Kōkaryō. It is more weakly pleochroic than aegirine: X = light green with bluish shade or light brownish green with bluish shade, Y = light green with brownish shade, Z = light greyish green or light brownish green. Its extinction angle, $Z \wedge c$, is 65° in the maximum case.

Barkevikite is absent in most specimens except in the coarser variety from Rokkutsu. It has a long anhedral form with a characteristic pleochroism: X = light brownish yellow, Y = reddish brown, Z = deep brown. Absorption: $Z>Y>X$. This mineral shows a high birefringence and is optically negative. The extinction angle: $Z \wedge c = 5°$. The largest crystal is 1·1 mm. in length and the mineral is often surrounded by a narrow fringe of aegirine.

Biotite is an important mineral in the specimens from Rokkutsu and Kōkaryō, and shows pleochroic colour a little different from the common variety: viz., X = light yellow, Y = yellowish brown, Z = reddish brown. Absorption: $Z>Y>X$. The birefringence is very high and $2V$ is extremely small. It has a tabular or flaky habit with distinct cleavage parallel to (001). The basal diameter is 2 mm. in the largest crystal. Magnetite is usually associated with it, but rarely aegirine.

Apatite is more abundant in the coarser variety in which it appears as a long prismatic or stout prismatic crystal. The largest crystal is 1·6 mm. in the maximum length and 0·2 mm. in the maximum basal diameter. Many hexagonal sections are seen under the microscope.

Magnetite is mostly represented by a titaniferous variety which frequently has a reaction rim of biotite. It partly alters to leucoxene or titanite.

Analcite is a remarkable constituent in teschenite, filling the spaces between other minerals. It is noteworthy that this mineral is closely associated with aegirine and aegirine-augite which are undoubtedly of a primary origin. The mode of occurrence of analcite is entirely similar to those of trachydolerite from the Kainei district of Korea and also analcite diabase in California. The evidence seems to be more in favour of its being primary analcite. Chlorite and calcite, however, are mostly of secondary origin and due to weathering. Calcite generally replaces plagioclase and partly forms irregular veinlets. Although this mineral is entirely absent in barkevikite-aegirine-bearing teschenite, it is abundant in some specimens from Kōkaryō. Nontronite has a yellow or greenish yellow colour and is evidently secondary and derived from some ferro-magnesian mineral. Even in the slightly weathered specimens this mineral is frequently seen together with chlorite. The original mineral is uncertain, but it is most probable that it was olivine, which is easily changed to this mineral on weathering, as shown by many other examples. It may also result from biotite. As will be understood from the microscopical investigation it is evident that plagioclase, apatite, magnetite, biotite, and barkevikite were formed in an earlier stage of crystallization. Among them apatite is earliest, and was succeeded by magnetite and biotite. The formation of biotite took place a little later than that of magnetite, as shown by the reaction rim around the latter mineral. Some of the plagioclase includes magnetite or biotite and is partly of later origin than these minerals. The later plagioclase is more acidic. Titaniferous augite sometimes contains plagioclase laths and shows a typical poikilitic structure: it was thus crystallized out after plagioclase. Soda-rich minerals, such as aegirine, aegirine-augite, and analcite are final products of the intruded magma, after which it might be expected to pass into the hydrothermal stage.

Many of the specimens collected from Rokkutsu, Kōkaryō, and elsewhere are much affected by weathering. It is, therefore, difficult to get fresh ones suitable for chemical investigation. Only three of them of relatively fresh appearance were selected for chemical analysis. The results are shown in the table on p. 72.

In the results of chemical analyses (1), (2), and (3), the anomalous composition of these rocks is indicated by high percentage of titaniferous oxide due to the presence of abundant titaniferous augite, biotite, titaniferous magnetite, and titanite. The remarkable quantity of combined water seems to be a result of weathering. The chemical composition somewhat resembles those of teschenite from Minussinsk in Siberia and Mapletown Township, Maine, U.S.A.

Some of these alkaline rocks are similar to the trachydolerite from the Kainei district of Korea, in mineral and chemical composition.[1] There are also resemblances to the analcite-diabase from the San Luis Obispo and Ventura Counties of California.[2]

	(1)	(2)	(3)	(4)	(5)
SiO_2	48·10	48·74	47·56	48·25	46·77
Al_2O_3	15·64	15·84	13·21	17·38	14·91
Fe_2O_3	6·80	6·90	6·65	4·51	7·80
FeO	2·78	2·82	2·98	5·31	4·90
MgO	3·80	3·85	3·59	2·13	2·94
CaO	7·77	7·88	5·04	6·03	6·30
Na_2O	2·61	2·65	4·20	5·81	4·97
K_2O	3·49	3·54	4·64	3·00	2·37
H_2O+	4·40	4·46	5·11	3·85	4·28
H_2O-	1·32	—	—	—	0·92
TiO_2	2·26	2·29	4·23	2·73	2·31
P_2O_5	1·66	1·68	2·21	0·65	0·29
MnO	tr.	—	—	0·65	0·29
Total	100·63	100·68	99·42	100·64	99·90

Norm.

	(1)	(2)	(3)
Quartz	4·98	4·74	—
Orthoclase	20·57	21·13	27·24
Albite	22·01	22·53	20·44
Anorthite	20·57	20·57	11·68
Diopside	6·36	6·58	—
Olivine	5·65	5·65	10·18
Acmite	—	—	13·40
Ilmenite	4·26	4·26	0·46
Hematite	6·80	6·90	2·08
Rutil	—	—	4·00
Apatite	4·03	4·03	5·38

(1), (2), and (3).—Teschenite from Rokkutsu. Analysed by T. Kōno.
(4).—Teschenite from Minussinsk, Siberia.[3]
(5).—Teschenite from Mapleton Township, Maine, U.S.A.[3]

Besides the above-mentioned locality for teschenite, the same rock was recently discovered by the writer in many places in the Tertiary coal-fields partly covering Taihoku Prefecture. These localities have been already mentioned in his brief note.[4] Many other localities are furthermore to be expected in the same district. The teschenites collected by the writer from various localities have nearly the same petrological characters as shown by those of Rokkutsu. They are all intrusive into the Miocene sediments.

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[1] T. Ichimura, "Alkaline Rocks from the Frontier Region near Kainei, Chōsen (Korea)." This paper will soon be published.

[2] H. W. Fairbanks, "On Analcite Diabase from San Luis Obispo County, California," *Univ. Cal. Publ. Geol.*, i, 1895, 273–300. N. L. Taliaferro, "Analcite Diabase and Related Rocks in California (Abstracts)," *Geol. Soc. Amer.*, Program (Cordilleran Section), 1930, 9–10.

[3] H. Rosenbusch, *Elemente der Gesteinslehre*, 1923, 462.

[4] T. Ichimura, "Brief Notes on the Alkaline Rocks of Taiwan," *Trans. Nat. Hist. Soc., Formosa*, xix, No. 103 (1929), 376–81.

The writer is particularly interested in the occurrence and origin of these alkaline rocks, although it is still questionable whether Dr. Daly's theory can be applied to our case in Formosa or not. If the crustal movement and migration of magma were, on the other hand, a cause of the local differentiation and accumulation of the alkaline magma, it would be more interesting to study these rocks in Formosa where they have been subjected to severe disturbance up to recent geological times. The writer is much indebted to Professor P. G. H. Boswell for kind reading of the preliminary manuscript and he wishes also to thank Mr. T. Kōnō for his chemical analyses of these rocks.

The Pattern of a Contracting Earth.

By A. J. Bull, M.Sc., F.Inst.P., F.G.S.

(PLATE II.)

THE most generally accepted explanation of the formation of mountains has been that of a slowly contracting earth with a solid crust accommodating itself to a shrinking interior. As the assumed shrinking proceeds, so the crust has to fold and fracture in order to occupy a smaller area. Such movements, particularly folding, would be facilitated by the hot glassy substratum on which the crust is believed to rest. Now it might be supposed on general grounds that wherever the crust was at all uniform in texture some regular pattern of folds or fractures would be formed. Since the floors of the oceans, particularly the Pacific, are believed to be fairly uniform, and to consist largely of basaltic material, these should show the pattern well; but the continents in spite of their more varied constitution should also show something of a regular pattern. Therefore if one could ascertain what would be the pattern of a contracting sphere, then this should be tracable in the tectonic structures of the earth's crust, and if the thermal contraction hypothesis is the real cause of these structures, in this way it should be possible to apply a crucial test to the validity of the hypothesis.

Thus far, experiments on this subject have been few and inconclusive. Chancourtois (1)[1] described in 1878 an experiment he had made twenty-five years previously in which he had used a contracting sphere consisting of a rubber balloon, which had been lightly oiled and then coated with wax. On contraction, due to cooling or partial deflation, a pentagonal pattern of ridges was obtained in the wax, which he regarded as analogous to mountain chains. Chancourtois also refers to the pattern on dried peas, which is often pentagonal, but usually contains some rough hexagons.

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[1] Figures in parentheses refer to References at end of article.

Lord Avebury (2) points out that experiments on mountain building have generally consisted in compressing materials in one direction only, whereas "If . . . folded mountains are caused by compression due to contraction of the earth, the compression must take place in two directions at right angles one to the other". He devised an experiment in which layers of carpet baize and sand were compressed in two horizontal directions simultaneously, and the forms taken by the baize were examined. The upper layers were, on the whole, not so much folded as the lower ones, there being marked disharmonic folding, a point brought out by Hudleston and Monckton in the discussion on this paper. Dr. Johnston-Lavis suggested that the contraction of a rubber sheet attached to a ring and stretched over the top of a cylinder might be a better form of the experiment. No decided pattern was indicated by Avebury's experiments, but an examination of the photographs shows that in several places three anticlines meet at a point.

Quirke (3) describes an experiment which consists of deforming by external pressure a rubber ball coated with wax. The ball was filled with air and surrounded by water, and the pressure was applied by the latter. It was found that the wax developed a belt of folding along a great circle, or sometimes two belts along circles crossing roughly at right angles. These Quirke compares with the major belts of mountain folding of the earth, and argues that these latter result from general contraction, and that the unaffected regions of the crust act as structural arches or domes sufficiently strong to withstand the stress.

It may be urged in criticism of Quirke's experiment that there is nothing corresponding to a movement of the crust on a glassy substratum as in Chancourtois' experiment, for the compression is not localized tangentially in a sphere, but being an external hydrostatic pressure it merely crushes the weaker parts of the shell. No proof whatever is offered that the earth's crust can "transmit vast stresses through members hemispherical in size to a zone of almost universal relief", while against this may be noted the opinion of Oldham (4) that it is impossible for such stresses to be transmitted far through the earth's crust, nor is any attempt made to relate the experiment to such salient facts as the intermittent character of mountain building periods and the state of repose or tension of large sections of the crust for long periods of time. It is for these reasons that the writer does not consider the conclusions drawn from the experiment to be justified.

The writer has repeated Chancourtois' experiment, and also carried out the one suggested by Johnston-Lavis. Both give the same results, but the latter is by far the more manageable form of the experiment. Numerous materials were tried, such as various waxes, collodion, gelatin, and Papier Josef. In each case the layer of

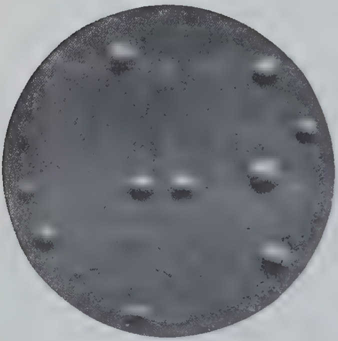

Fig. 1.

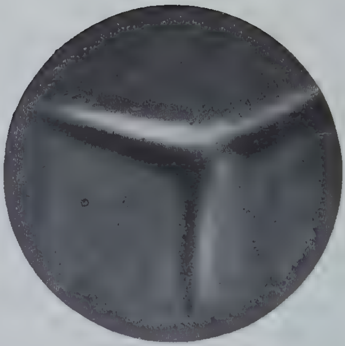

Fig. 2.

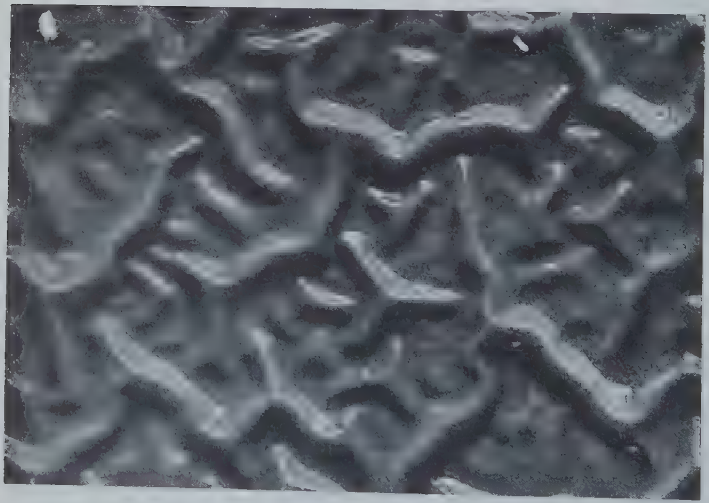

Fig. 3.

Fig. 1.—The first form produced in a flexible layer contracting in its own plane is a small dome.

Fig. 2.—Three anticlines coming out from a dome; one of these has stretched out to join another anticline.

Fig. 3.—Network produced by the joining of anticlinal ridges.

To face p. 75.]

material being used for the experiment was put down upon the stretched rubber, with a suitable layer of viscous material between them, for instance, glycerine, water, or medicinal paraffin. When the contracting layer was brittle then the network of cracks described by Chancourtois was obtained. These cracks form a pattern of pentagons with hexagons and occasionally a trapezium, but in almost all cases it is three lines that meet at a point. With materials that will fold, small rounded elevations or domes appear (Plate II, Fig. 1), which may become so closely packed that they cover the entire surface. This happens when there is little viscous liquid to flow below the folding layer, but with a little greater freedom of movement each dome sends out three radial pitching anticlines. Where these meet each other in line they join up and form a network of anticlines. Fig. 2 shows one such set with one anticline stretching out to join with another. When the sets of anticlines start quite independently some will join while others will not. This is well seen in Fig. 3, where some of the ridges meet each other at a large angle and can grow no further, while others join to form a network in which 120 degrees is the dominant angle. In some places will be seen some good examples of the unit form of three pitching anticlines radiating from a point. In cases where the outer surface of a contracting sphere is a flexible shell with considerable soft material below, a complete network is formed consisting largely of hexagons.

The results of a large number of experiments indicate that the patterns described are characteristic of a contracting sphere, and while the want of homogeneity in the earth's crust would make for irregularity, the pattern produced by three anticlines or fractures meeting at a point should be the foundation of all tectonic structures. This is not a characteristic mountain form, and if it occurs at all is rare. It may therefore be concluded that the structures of the earth's crust have not been produced by a general contraction.

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(2) Lord Avebury, *Quart. Jour. Geol. Soc.*, lix, 1903, 348.

(3) T. T. Quirke, *Comptes-Rendus XIV^{e} Congrès Géol. Inter.*, 1926 (Madrid, 1929), 1537.

(4) R. D. Oldham, *Quart. Jour. Geol. Soc.*, lxxvii, 1921, lxxxix.

EXPLANATION OF PLATE II.

Fig. 1.—The first form produced in a flexible layer contracting in its own plane is a small dome.

Fig. 2.—Three anticlines coming out from a dome ; one of these has stretched out to join another anticline.

Fig. 3.—Network produced by the joining of anticlinal ridges, in several places groups of three pitching anticlines are to be seen radiating from a point. The material in the experiments illustrated was a pile of collodion films containing Silver Iodide.

The Age of the Lundy Island Granite.

By E. H. Davison.

IN the Geological Survey Memoir on Ardnamurchan, North-West Mull and Coll, it was stated[1] that the Lundy Island granite is very similar to the granites of Mourne Mountains and Arran, and is probably of Tertiary age. As this suggestion seemed to be contrary to the opinion of geologists familiar with the West of England, who generally consider the Lundy Island granite to be of the same age as the granites of Devon and Cornwall, it was thought desirable to settle the question, if possible.

In the work quoted above it is stated that :—

(i) " The Tertiary age of certain less important centres of intrusion may be inferred from the rock types and structures presented by the various masses and of these may be mentioned the Wolf Rock (phonolite) south of Lands End, Lundy Island (granite) off the north coast of Devon, and Ailsa Craig. In addition there are minor plugs and bosses, such as those of Mull, South Argyll, etc."

(ii) " The island (Lundy) is formed of a mass of granite, which presents remarkable similarity to that of the Mourne Mountains."

(iii) " Granites are the chief types in the Mourne Mountains, Lundy Island, and North Arran."

In order to test the suggested similarity of Lundy Island granite to the other granites, specimens were obtained from each locality, and were subjected to mechanical analysis and microscopic examination. The mineral composition of the various types is shown in the following table :—

Mineral Components.

Locality.	Orthoclase.	Albite.	Biotite.	Muscovite.	Tourmaline.	Fluorite.	Topaz.	Apatite.	Zircon.	Hornblende.	Other Minerals.
Mourne Mts.	Much	Some	Much	V. Little	—	—	—	Some	Some	—	—
Arran	Much	Some	Much	V. Little	—	—	—	Some	Some	Some	Sphene
Mull	Much	Some	Much	V. Little	—	—	—	Some	Some	—	—
Lundy Island	Much	Some	Little	Much	Some	Some	Much	Some	Some	—	Cassiterit
West of England	Much	Some	Some	Much	Much	Some	Some	Some	Some	—	Cassiterit

These results suggest a much closer relation between the Lundy Island and West of England granites, especially in the fact that these two types are rich in minerals indicating the presence of the fugitive constituents of the magma, while the Mourne Mountain, Mull, and Arran granites are practically devoid of such minerals.[1]

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[1] *Geol. Ardnamurchan, N.W. Mull and Coll.*, 1930, 55 and 61.

Further, a large proportion of the white mica in the Lundy and West of England granites, though classified under the heading muscovite, is actually lepidolite or gilbertite mica, while these types of mica were not found in the other granites.

A further test was made by measuring the widths of the pleochroic haloes round the zircons included in the coloured minerals. As Joly has shown, the width of the halo is proportional to the age of the granite in which it occurs.

The results obtained were :—

Locality.	No. of Measurements.	Maximum.	Minimum.	Mean Width of Halo in Micro-millimetres.
Lundy Island .	24	32·5μ	28·7μ	30·1μ
Mourne Mountains	16	11·2μ	8·5μ	9·5μ
Arran . .	12	11·5μ	8·2μ	9·4μ
Mull . . .	19	12·0μ	8·2μ	10·1μ
West of England .	65	32·6μ	28·5μ	30·3μ

These results, again, show definitely the close relation between Lundy Island granite and that of the West of England, while there is a marked difference between the Lundy granite and the Tertiary granites with which it has been compared.

In conclusion the mineral composition, textures and pleochroic haloes of the various granites seem to indicate that the Lundy Island granite is of Post-Carboniferous age, like the granite of the West of England, rather than of Tertiary age like the granites of Mourne, Mull, and Arran.

The author's thanks are due to Mr. F. W. Jade, of Lundy, for help in obtaining specimens of the granites.

Orbicular Rocks in the Channel Islands.

By A. E. Mourant, M.A., D.Phil.

(PLATES III AND IV.)

THE publication by Mr. S. R. Nockolds (8) [2] of a description of an orbicular diorite from Alderney prompts the writer to publish forthwith an account of a similar rock from that island, which he has examined.

Mr. Nockolds deserves every credit for being the first to publish a detailed description of these rocks, but it may perhaps be mentioned that the writer's discovery was made in March, 1927, and announced (6) in 1928.

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[1] In the Mourne Mountains granite topaz and beryl occur in drusy cavities.

[2] Numbers in parentheses refer to the bibliography at the end.

A full description of the occurrence is warranted since the orbs are much more abundant and many times larger than those described by Mr. Nockolds, and show a number of additional features bearing closely on the origin of the bodies and in some cases, in fact, confirming in no uncertain manner his tentative conclusions drawn from less perfect examples.

When Mr. Nockolds's account appeared, the writer had just completed a description of some of the plutonic rocks of Alderney for a purpose other than immediate publication, but it now seems desirable that it should be published with as little alteration as possible, and any material additions placed as footnotes or as notes at the end. In what follows omissions are indicated thus, . . ., and additions are placed between square brackets.

The gabbros, diorites, and granites of Alderney have been described by Hill (1), Bonney and Hill (3), Plymen (4), and Groves (5).

Bonney and Hill describe the apparent invasion of picrite by diorite at Fort Albert, and the veining of both by felspathic rock, but Plymen was the first to describe the invasion of basic rock by granite [e.g. at Corblets Bay], and to compare the Alderney plutonic rocks to Parkinson's Jersey " differentiation series " (2).

Groves was the first to describe a hypersthene gabbro as such. According to him the northern granite is, in his own nomenclature, of " newer " age, and the southern of " older ".

A consideration of the above four papers suggests that the plutonic series of Alderney is of great interest. A comprehensive field and petrographic survey is much to be desired.

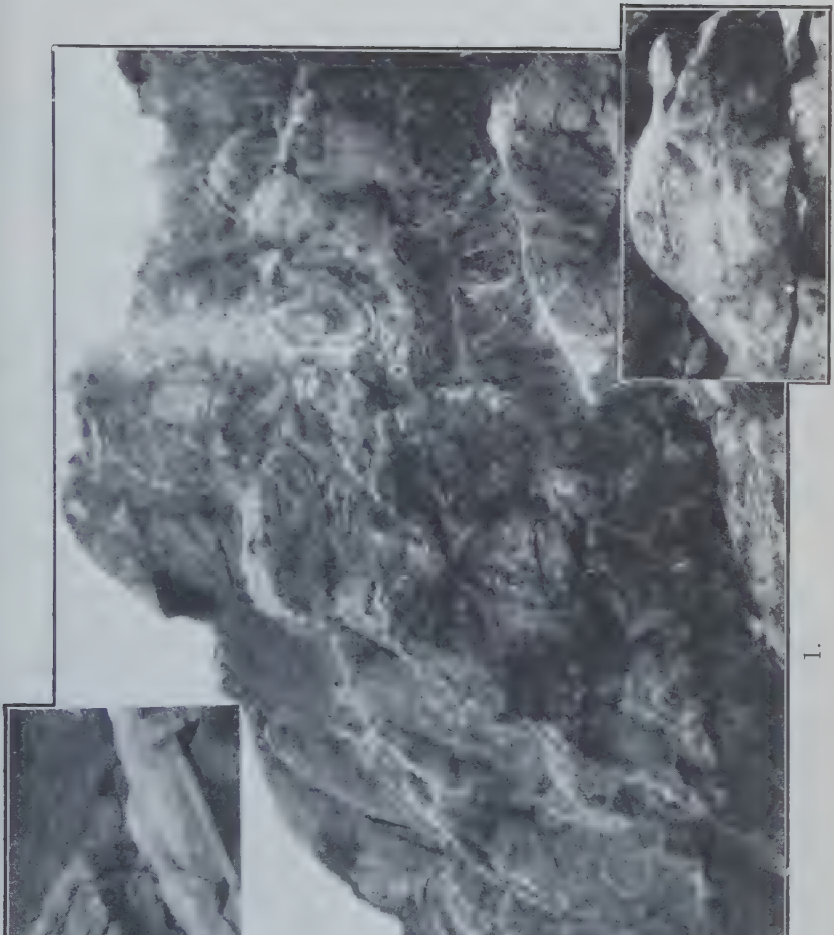
Perhaps the most remarkable area is that between Roselle Point and Bibette Head, on the north coast.

Bibette Head itself consists of a grey granite described by Hill and later by Plymen. It consists mainly of white felspar, quartz, hornblende, and biotite, and contains abundant small basic xenoliths, often with large felspar phenocrysts. It resembles very closely the granites of Herm and Jethou, and to a considerable degree that of Sark.

Most of the bay is occupied by a speckled rock of dioritic aspect. Just east of Roselle Point a small patch of this rock, mostly just above high tide level, is crowded with large orbicular structures (Plate III, Fig. 1).[1] It is surprising to find that previous workers had not seen these remarkable examples of a structure almost unknown in the British Isles.

Immediately to the north is a small patch of coarse lustrous greenish-black rock, closely welded to the " diorite ", so that it is almost impossible to tell which is the earlier.

[1] This point may be found by descending to the foreshore just west of Bibette Head and scrambling westward along the rocks at the foot of the cliff until a deep gully compels one to climb the low cliff in order to cross it. The orbicular rock is immediately west of this gully.



Orbicular Rocks in Alderney and Guernsey

[*To face p.* 78.

A larger patch of the same rock occurs on the western side of Roselle Point, and is described by Hill (1) as picrite. As mentioned above, Bonney and Hill finally conclude that it is older than the "diorite". . . .

PETROLOGY.

Bonney describes the petrology of the "picrite" of Roselle Point in Hill's first paper (1) on Alderney. The rock contains [according to him] olivine, augite, pleochroic pyroxene (evidently hypersthene), hornblende, and biotite—a surprising variety of ferromagnesian minerals—together with indeterminable plagioclase and iron oxides. Pleochroic pyroxene grows around augite, and hornblende round pyroxene.

The "diorite" of the centre of the bay is shown by Groves (5) to be a gabbro consisting of hornblende, biotite, and decomposed basic plagioclase, and containing sponge-like cavities filled with quartz.

The smaller, more easterly patch of the dark lustrous rock was found by the writer to combine some of the features of both the rocks just described.

The rock is of a coarse granitic texture, consisting mainly of augite, hypersthene, hornblende, biotite, plagioclase, and quartz (Plate IV, Fig. 1).

The augite is almost colourless, and generally presents jagged reaction margins to later minerals.

The hornblende is pale in colour, with X very pale yellowish, Y olive, Z slightly bluish green. It thus resembles to some extent actinolite from Zillerthal.[1] . . . It occurs either alone or surrounding augite, in which case the cleavage traces in the two minerals, when only one set is visible in each, are sometimes but not always parallel. One case occurs of a graphic intergrowth of hornblende and augite. Hornblende occasionally, but not always, presents idiomorphic outlines to felspar.

The hypersthene is pleochroic from very pale green to exceedingly pale reddish, with small patches of deeper brownish colour. It is generally more or less idiomorphic, and usually occurs alone, but in one case it surrounds an augite crystal, while another hypersthene crystal contains odd bits of augite.

Biotite forms a few large crystals. It shows pleochroism from deep chestnut to pale straw colour. It is idiomorphic against hornblende and felspar, but hypersthene is discoloured on contact with it.

The felspar is fairly fresh, and has approximately the composition $Ab_{52}An_{48}$—a basic andesine.

Quartz appears to be intrusive. It fills large sponge-like hollows in the rock. Large areas, not connected in the plane of the section, are optically continuous. It shows strain shadows arising from the corners of earlier minerals and crystals of the last appear to be floating in it. Augite, hypersthene, and perhaps hornblende have sprouted fibrous outgrowths into the space now filled by quartz. These are generally, but not always, optically continuous with the parent crystals.

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[1] J. P. Iddings, *Rock Minerals*, New York and London, 1906, p. 360.

Secondary muscovite and chlorite are present.

The absence of the olivine noted in the neighbouring similar rock by Hill (1), the conversion of augite into hornblende and hypersthene, and the presence of apparently intrusive quartz point to the action of an acid magma. This is obviously the granite of Bibette Head, and the same magma has produced the quartz in the gabbro described by Groves (5).

THE ORBICULAR GABBRO.

The orbicular gabbro is a local development of the main gabbro of the bay. The orbs vary in diameter from a few inches to a foot. Most of them show concentric, approximately circular bands, alternately richer in felspar and dark minerals. In some cases broken segments of orbs have grown new continuous outer zones.[1] In others, subangular fragments of straight-banded gabbro are surrounded by continuous curved zones (Plate III, Fig. 2).

There is generally a fine-grained, fairly large, unzoned nucleus, looking, if anything, paler than the matrix.

The exposed material, being mostly above high-tide level, is weathered, and not very suitable for petrographic examination. . . .

A thin section has been examined, which shows an almost complete sector of an orb. (Plate IV, Fig. 2.)

The principal primary minerals are augite, hornblende, biotite, and plagioclase felspar. The last is intensely sericitized, but seems to be constant in composition throughout the slide—an andesine, rather more acid than that of the hypersthene gabbro.

In Fig. 2 of Plate IV, zone 1 is the outer part of the nucleus. The grain-size is ·3 to 1 mm. This part consists of hornblende, pale augite, and intensely sericitized plagioclase with almost perfectly clear spots. The hornblende is pleochroic from straw-yellow to green with an olive tinge. There are also large amounts of an indefinite yellowish-green mineral, apparently secondary after ferromagnesians.[2] To this change is [partly] due the pale colour of the nuclei of many of the orbs. . . .

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[1] Fragments of orbs also occur which have not healed over.

[2] As mentioned below, this mineral is distinct from the chlorite derived from biotite. It looks rather like serpentine, and is biaxial negative, closely resembling Mr. Nockolds's antigorite. On the other hand, the original mineral was produced by reaction between xenolith and magma, and thus cannot have been olivine. Its shape and manner of occurrence suggest that it was hypersthene. The altered material is thus probably bastite.

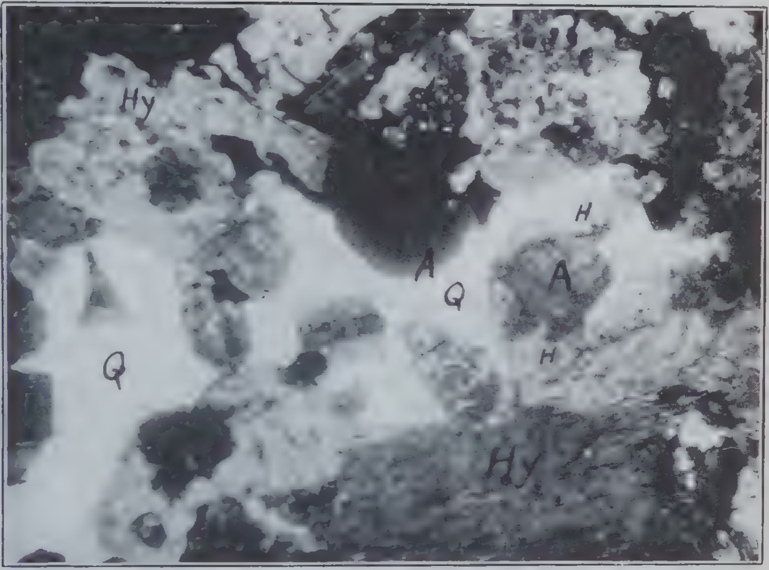

FIG. 1.

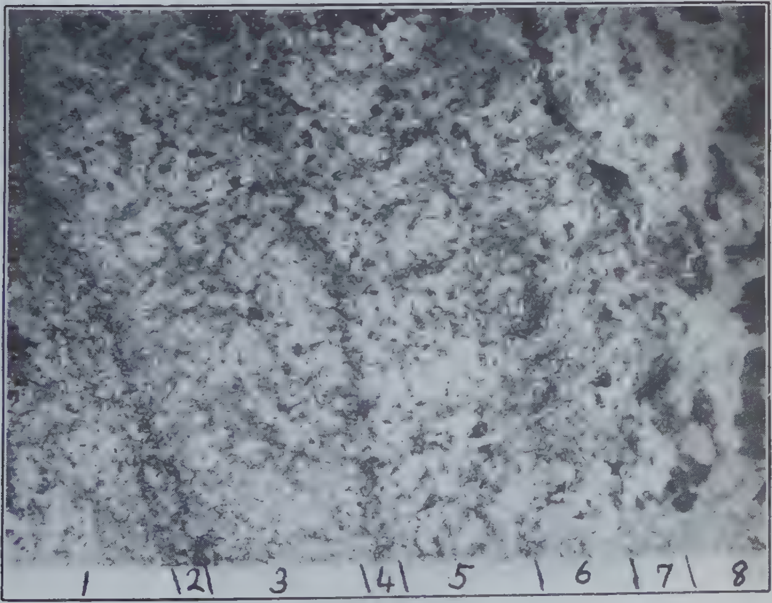

FIG. 2.

THIN SECTIONS OF ALDERNEY GABBROS.

[To face p. 80.

The next zone, 2, is richer in coloured minerals, especially the yellowish material just mentioned. Zone 4 is similar; while Nos. 3 and 5 resemble the nucleus. In these two some of the augite appears to be bordered by hornblende.

Zone 6 is broad and fairly rich in coloured minerals. Definite though much altered biotite here appears for the first time. It is quite distinct from the yellowish mineral mentioned above. Hornblende is abundant, but there is little augite. Zone 7 contains still more coloured minerals, especially biotite with augite inclusions. There is much hornblende and yellow mineral, but little augite except in the biotite.

In the matrix, marked 8, the grain-size, which has been increasing outwards, is much larger, 1 mm. and over. Much hornblende is present here—some of it enclosing biotite and felspar. Some hornblende shows polysynthetic twinning. Biotite crystals are also present, some with augite between the cleavage planes. Augite is, on the whole, rare. Much of the yellowish mineral is present, also a similar greenish one resembling chlorite. In one case hornblende has crystallized around the yellow mineral. Much felspar is present.

The felspar varies in clearness from zone to zone, being clearest in Nos. 5 and 8.

In the body as a whole the most conspicuous structure is the concentric zoning, but traces of radial arrangement are seen in zones 3 and 5.

The matrix of this rock greatly resembles the gabbro described by Groves. The orb, however, is richer in augite and its fine grain suggests recrystallization. The form of the orbs, moreover, shows that they are xenolithic in origin. (See Plate III, Figs. 1 and 2.)

Considering the proximity of the older gabbro, rich in augite, described above, it is highly probable that the orbs are due to a sort of periodic crystallization or recrystallization around xenoliths of this material. That they are not merely reconstituted xenoliths right up to the periphery is shown by the fact that angular cores are surrounded by curved zones. The latter must be due to crystallization from the surrounding magma.

The remainder of this paper has been written since the publication of that by Mr. Nockolds (8).

Without entering into further theoretical discussions, it is now clear that not only all the orbs, but also Nockolds's "spheroidal inclusions" are derived from Hill's "picrite". The "surrounding diorite" of Nockolds is Groves's "gabbro", while the "normal diorite" appears to be something between the "gabbro" and the "picrite".

In the above account the far-reaching effect of mutual reaction between the xenoliths and the surrounding magma was not, perhaps, fully realized. The pale colour of the cores is evidently due not only to hydration of the ferromagnesians, but to the migration outwards of the elements composing them to react with the magma and form one or more zones rich in coloured minerals. The volatile elements which facilitated this process were clearly abundant at Roselle Point as at Corblets Bay.

GUERNSEY.

Orbicular structure is also found in the north-west of Guernsey. In the midst of the gabbro in the bay of Grand Camp, associated with a granitic intrusion, one perfect orb about 18 inches in diameter is found (Plate III, Fig. 3). There are also traces of others, rather suggestive of shells washed away from their cores by the highly contaminated granite magma. The perfect one is situated about 3 yards north of the foot of the high rock on which a small rounded stone is set up as a beacon. It closely resembles the Alderney bodies, and is probably of similar origin, but more acid in composition; being developed by reaction and crystallization around a gabbro xenolith in the little acid intrusion. A further search revealed nothing more than the traces mentioned, but it would be very surprising if this were the only one of these objects exposed in the whole of Guernsey.

Not a sign of similar structures has been seen in the mixed plutonic rocks of the other Channel Islands. This is probably because of the movement which accompanied the granite-gabbro mixing, and which has been noted particularly by Wells and Wooldridge in Jersey (7).

I wish to thank Dr. J. A. Douglas, Professor W. J. Sollas, and Mr. R. C. Spiller for help and criticism.

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EXPLANATION OF PLATES III AND IV.

PLATE III: ORBICULAR ROCKS IN ALDERNEY AND GUERNSEY.

FIG.

1.—Orbicular gabbro near Roselle Point, Alderney, looking east. The height of the main face is about 10 feet.

FIG.
2.—Boulder of orbicular gabbro near Roselle Point, Alderney, showing straight-banded xenolith surrounded by curved bands. The boulder is about 1 ft. 6 in. long.
3.—Orbicular diorite, Grand Camp, Guernsey.

PLATE IV: THIN SECTIONS OF ALDERNEY GABBROS.

1.—Hypersthene gabbro from near Roselle Point. × 31·5. Crossed Nicols. A, Augite; Hy, Hypersthene; H, Hornblende; Q, Quartz.
2.—Orbicular gabbro from near Roselle Point. × 5·7. Ordinary light. The numbered zones are described in the text.

Some Recent Contributions to the Pleistocene Succession in England.

By J. REID MOIR.

I HAVE read Dr. Sandford's important note on "Some Recent Contributions to the Pleistocene Succession in England" (GEOL. MAG., LXIX, No. 811, January, 1932), with much pleasure and profit. So long ago as 1920 I published in the GEOLOGICAL MAGAZINE ("The Geological Age of the earliest Palaeolithic Flint Implements", LVII, No. 671, May, 1920) a communication in which I expressed the then unorthodox belief that the palaeolithic implements of England were not—as was at the time generally supposed—of post-glacial age, but were made by races of people living in warm epochs intervening between the various glacial periods. In this note I also, for the first time, made a tentative correlation of the East Anglian glacial deposits with those studied by Penck and Brückner in the Alps, and it is of much interest to me to notice how my initial work has been extended by others, among whom Dr. Sandford takes a foremost place. It is also gratifying, human nature being what it is, to find that so much of my original correlation has stood the test of time, and that my claim that the Upper Chalky Boulder Clay is of *Riss* age, which received much condemnation, now finds itself supported by the powerful advocacy of my friend the Abbé Breuil.

There are one or two points in Dr. Sandford's note to which I would like to call attention. In summarizing Professor Boswell's views on the East Anglian succession, he states (p. 3) that "the so-called Weybourne Crag glaciation and Cromer Forest Bed warm period are myths", but, with due respect to my colleague's opinion, I would venture to question this. It is not possible in this communication to set forth, in detail, my reasons for objecting to the dismissal of the above-mentioned geological happenings as mythical, but, after many years digging in the Suffolk Bone Bed beneath the Red Crag, and in the Stone Bed below the Norwich and Weybourne

Crags, I am more than ever convinced that the pre-Crag land surface of East Anglia was subjected to a glaciation, and that the agency of floating ice is inadequate to account for the widespread evidence of extreme cold to be found in the detritus of that land surface now buried beneath the Crags. In a monograph I am now preparing for the Field Museum of Chicago, I hope to deal fully with this important matter. As to the series of deposits known as the Cromer Forest Bed, the great majority of the mammalian remains found in it, can only surely be regarded as those of warmth-loving animals? I have always referred to the Cromer Forest Bed epoch as "The First Inter-Glacial period of East Anglia" when Chellean man lived in England, and to this opinion I am sufficiently recalcitrant still to adhere. But the future will no doubt show whether my friends or I are right in our respective views.

Again, on page 4 of his note, Sandford, quoting Boswell, states that Lower Acheulean implements have been found in the lowermost brickearth overlying the basal Boulder Clay at Hoxne, Suffolk. This, however, is incorrect as, so far, no remains of man have been recovered from the particular brickearth (in reality a lacustrine silt) mentioned. It is at this horizon where it might be expected Lower Acheulean implements would occur, but, so far, such a discovery has not taken place. In the diggings carried out by Boswell and myself at Derby Road, Ipswich,[1] where there exists, in my opinion, a series of beds contemporaneous with those at Hoxne, some specimens were found in the lowermost implementiferous deposits which may well be of Lower Acheulean age, and it is to these, perhaps, that Sandford refers?

I hesitate to become involved in a discussion as to the contemporaneity in age of the beds in the Thames Valley with others in East Anglia, but, on a recent visit to Swanscombe, the conclusion was forced upon me that the series at that place dealt with by Sandford, is to be relegated to the Second Inter-Glacial period of East Anglia; that is, to the epoch represented at Hoxne, Derby Road, Ipswich, and High Lodge, Mildenhall. At the latter sites the implementiferous beds are surmounted by the Upper Chalky Boulder Clay, while at Swanscombe the "series" mentioned is succeeded by the Coombe Rock, which I believe to be the equivalent of the Upper Chalky Boulder Clay. The important question of the age of the Hunstanton Boulder Clay cannot yet be looked upon as settled, and I am continuing my investigations in the region of north-west Norfolk with a view to its elucidation. My present inclination is to regard this Boulder Clay as having been laid down in post-Aurignacian times, and that the Solutrean and Magdalenian epochs are represented by the oldest Fen Beds which, as we know, immediately overlie the Hunstanton, or Brown Boulder Clay. There is some significant, though admittedly scanty, evidence of the presence of Solutrean implements deep down in the Fen, from which also, it is well to remember, reindeer has been recorded.[1] The whole question of the Pleistocene Succession in England is of a highly complex nature, but with such competent investigators as Boswell, Sandford, Burchell, and Solomon, to mention but a few, engaged upon it, its solution cannot, it seems, be long delayed.

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[1] *Journ. Roy. Anthro. Inst.*, liii, 1923, January to June, 229–62.

REVIEWS.

THE FOSSIL FLORA OF SCORESBY SOUND, EAST GREENLAND. By T. M. HARRIS. Meddelelser om Grønland, Bd. 85, no. 2, 1931, pp. 104, pls. xviii.

A VERY extensive collection of Rhaetic plants from Eastern Greenland was made in 1926–7 by Dr. T. M. Harris, who was a member of the Danish expedition under Dr. Lauge Koch. The present volume contains the first fruits of Dr. Harris's study, and deals mainly with the ferns and equisetalean plants. It will be followed by several further instalments, and a full discussion of Rhaetic stratigraphy and other general questions is reserved for the final part. (Meanwhile, however, Dr. Harris has given a summary of our knowledge of Rhaetic floras in *Biological Reviews* for April, 1931.)

The author has extracted the fullest possible amount of information from his material, with the aid of the latest methods of investigation, and particularly the bulk-maceration treatment devised by himself. These methods have revealed elements in the flora which would otherwise have been overlooked—two or three liverworts and an alga, for example—and have yielded a wealth of detailed information concerning sporangia and spores, cuticles and stomata, and even rhizoids, of the plants described. There are numerous new species (a list of contents would have been useful, for the scanty index does not state which are new), and all of them are admirably described. The "diagnosis" of *Neocalamites carcinoides* occupies more than a page and a half; it is not, of course, a diagnosis at all, but a very full and complete description. The revision of the genera *Marattiopsis*, *Todites*, *Cladophlebis*, and others will be useful to all workers in this field. The illustrations, both the numerous text-figures and the photographs, are exceptionally good, and palaeobotanists will eagerly anticipate the succeeding parts of Dr. Harris's monograph.

W. N. E.

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[1] Skertchley, *The Fenland Past and Present*, 327.

(1) AN OUTLINE OF THE HISTORY OF IGNEOUS ACTION IN NEW SOUTH WALES TILL THE CLOSE OF THE PALAEOZOIC ERA (Presidential Address). By W. R. BROWNE. Proc. Linn. Soc., N.S.W., vol. liv, part i, 1929, ix–xxxix, one plate.

(2) THE GEOLOGY OF THE SOUTH COAST OF N.S.W., Part III: the Monzonitic Complex of the Mount Dromedary District. By Miss IDA A. BROWN. Proc. Linn. Soc., N.S.W., vol. lv, part v, 1930, pp. 137–98, with four plates.

THESE recent papers form noteworthy contributions to the petrological literature of New South Wales and are of more than Australian interest.

(1) In his review of pre-Mesozoic igneous action in N.S.W. Professor Browne has given a clear, concise account of the character and sequence of intrusions and extrusions, and their relations to the crustal movements of each period. A variety of injections, including granitic gneisses and gabbros, accompanied the diastrophic revolution closing the Willyama (Pre-Camb.) sedimentation. Similarly, the foldings at the end of the Ordovician and Silurian periods were attended by stromatolithic invasions of granitic and quartz-dioritic gneisses and subordinate basic rocks.

Of the succeeding diastrophisms, that closing the Devonian (Süssmilch's Kanimbla epoch), was the most important, when great calcic plutonic complexes were injected. No extensive intrusions occurred during the Carboniferous, but hypabyssal rocks intimately related to the volcanic rocks of the period occur in the northern part of the State. The important late-Palaeozoic movements were characterized by another series of granitic intrusions, similar in many respects to the Kanimbla types, but the latest development of all was probably the remarkable alkaline monzonitic complex of Mount Dromedary (see below).

The vulcanicity of the various periods, particularly widespread in the Silurian, Devonian, and Carboniferous, gave rise to a great variety of types, embracing spilites, basalts, latites, andesites, toscanites, keratophyres and rhyolites, and their clastic associates, many of the series showing albitization.

Summarily, with the aid of a table, the relations between the tectonics and rock-types are considered, the general conclusions being that the spilitic and albitized lavas seem to show some connection with prolonged geosynclinal subsidence, while the calcite-granites and quartz-monzonites are related to the orogenic revolutions which interrupted the course of this vertical movement. The only alkaline injections of any consequence appear to be connected with emergence rather than submergence.

(2) In this paper Miss Brown has described an almost unique igneous complex embracing some rare rocks, and displaying a remarkable diversity of type. The mass is apparently laccolithic and of late Permo-Carboniferous age. The igneous rocks comprise

three plutonic series and a suite of minor intrusions of latites, lamprophyres and aplites. The plutonic series are: (*a*) a monzonitic group embracing banatite, porphyritic monzonite, quartz-monzonite, olivine-monzonite, shonkinite and jacupirangite; (*b*) a nepheline-bearing series with ijolite, nepheline-monzonite and nepheline-shonkinite (covite): (*c*) a melanite-bearing series of pyroxenites comparable with kedabekite and melteigite-jacupirangite.

The petrogeny of the rocks is discussed with the aid of variation-diagrams, based upon eleven analyses, ten of which are the work of the author herself. It is concluded that all of the rocks are co-magmatic, although there is greater affinity between (*a*) and (*b*) than between any other groups. The general thesis stated is that the normal monzonitic series differentiated in place by fractional crystallization, while the nepheline series represents a secondary differentiation of a phase of the monzonitic magma, squeezed out from the main mass during some subordinate crustal disturbance. The rare melanite-pyroxenites whose genesis is more obscure are treated in great detail, and comparison is made with similar occurrences in other parts of the world, especially that of the Fen district of Telemarken, Norway. While not making any final pronouncement upon their origin, the author inclines to the view that limestone has been assimilated by some phase of the monzonitic magma, and that from such contaminated liquid the melanite-pyroxenites have been produced.

G. D. OSBORNE.

EMIGRATION, MIGRATION, AND NOMADISM. By the late WALTER HEAPE. Edited by F. H. A. MARSHALL. pp. 368, with a portrait of the author. Cambridge: W. Heffer and Sons, Ltd., 1931. Price 12*s.* 6*d.*

AT first sight the subject of this book might not seem to have very much to do with geology, more especially as it is treated mainly from the point of view of the search by animals for breeding and feeding grounds. Naturally it deals very largely with annual migrations like those of the swallow and the salmon, and the movements *en masse* of animals such as the lemming and the springbok. But there can be no doubt that migration in some form or other must have played a large part in the distribution of organisms in past ages, though in the case of marine faunas passive drifting rather than voluntary travel may have been the chief agent. It is when we come to study the distribution of the animal remains in the latest formations, and especially the movements of animals in relation to the Pleistocene glaciations, that the subjects here discussed attain their highest significance. From this point of view the book is well worth study by geologists.

THE IGNEOUS ROCKS, PYROMETAMORPHISM AND ORE DEPOSITION AT TRAVERSELLA, PIEDMONT, ITALY. By W. Q. Kennedy. Bull. Suisse de Mineral. et Petrogr. = Schweiz. Mineralog. u. Petrogr. Mitt., vol. xi, part i, 1931, pp. 76–139.

THIS is a most interesting study of the petrography of the well-known mineral locality of Traversella, whence many fine specimens have come. The country rocks belong to the Sesia Lanzo zone of Alpine tectonics, which is considered to represent the roots of the Dent Blanche Nappe. These have been invaded by an igneous mass, of post-Alpine age, mainly of quartz-dioritic character, belonging to the same phase as the intrusions of Biella, Baveno, Bergell, and Adamello, which follow in order towards the E.N.E.

The most striking metamorphic effects are those that have been set up in the calcareous and dolomitic members of the country rock, and are specially characterized by diopside and garnet in varying proportions: other types yield spinel, olivine, plagioclase, and even orthoclase. One variety from a quarry near Riondella yields almost exactly the analysis of a theoretical diopside, carrying only about 1·8 per cent of iron oxides. The garnets are essentially andradite. All the rocks analysed come within, or on the boundaries of, the diopside-garnet-anorthite field of the usual ternary diagram for $MgSiO_3$, $CaSiO_3$, and Al_2SiO_5. These rocks are just typical skarn, and the author considers, undoubtedly with justification, that there has been diffusion of silica, alumina and a little ferric iron across the boundary of the intrusion, by solutions derived from the magma. In some localities there are rocks with hydrous silicates, chlorite, talc, and serpentine, some of which are primary, due to specially watery magmatic solutions.

The associated ores include magnetite, often associated with olivine, pyrrhotite, pyrite, and some chalcopyrite; other minerals known are galena, blende, scheelite, arsenite, and molybdenite. They occur mostly as veins deposited from late-magmatic watery solutions.

GEOLOGÍA ARGENTINA; Segunda parte: Geología Histórica y Regional del Territorio Argentina. Por el DR. ANSELMO WINDHAUSEN. Con 1 mapa geológica, 58 láminas, 214 figuras en el texto y 1 frontispicio. Buenos Aires: Jacopo Peuser.

ALTHOUGH Argentina has been the field of active geological exploration for many years—the official Geological Survey having been in existence for a quarter of a century—it is extraordinary that no comprehensive account of its geology has hitherto been written. All the more welcome therefore is this fine volume of over 600 pages, which gives in Spanish a remarkably clear and up-to-date account of the geology of a huge and very diverse territory, close upon 2,800,000 square kilometres in extent.

Although a good deal of it is of necessity compilation, much is original, the author, who now occupies the Chair of Geology at the long-established University of Córdoba, being well known for his important surveys in Patagonia, as well as the writer of numerous other papers of note. His descriptions are, moreover, not confined to Argentina, for the intimate relationships with the neighbouring republics of South America find adequate recognition, while the Falklands, South Georgia, etc., are appropriately included.

The stimulating introductory chapter, dealing with geological concepts, is short, though adequate, since the subjects of general and dynamical geology has been fully dealt with by Dr. Windhausen in a previous volume of 400 pages, also in Spanish.

Argentina is an uncommon type of country, built up of the rugged meridional chain of the Andes (Cordillera) on the west, towering to immense heights and feeding glaciers, more especially in the south: the somewhat detached and broken Pre-Cordillera immediately to the east; the great Pleistocene plains of the north-east and east; and the somewhat dissected tableland of Patagonia, fronting the Southern Atlantic. The Pre-Palaeozoic rocks have only a limited development in the north-west and west, the prevailing formations ranging from Cambrian to Recent and including numerous fossiliferous terrains. The author, in admirable fashion, supplements his accounts of such fossils by reference to the corresponding life of the remainder of South America and of the Northern Hemisphere, with a profusion of illustrations.

After treatment of the Cambrian of the north-west, the Ordovician and Devonian of the west, the latter with its curious "austral fauna", the Permo-Liassic "Gondwana" Beds of the central region are described with their basement glacials and succeeding *Glossopteris*-bearing strata, affected along a certain belt by post-Permian foldings. The term "Paganzo" is restricted to the younger division (Triassic). We next obtain a picture of the entry of the shallow Triassic sea from the north-west, its spread southwards during the Liassic and development into the lengthy and unstable Andine geosyncline, accompanied from the Rhaetic onwards by profuse volcanicity, both terrestrial and submarine, with emission of basalts, porphyries, and tuffs. Uhlig's contentions as to the absence of boreal elements in the abundant Andine Jurassic and the presence there of an important centre of organic evolution, are upheld. During the Cretaceous the ocean spread eastwards over Neuquen and southwards far into Patagonia, shallowing in parts owing to inter-Cretaceous movements that led to the transgression of the Senonian with its associated lacustrine deposits yielding abundant dinosaurian remains. Recent work has confirmed the opinion that these sauropods did not survive the Danian.

Fascinating is the picture given of the Tertiary: of the marine incursion over Patagonia and in between the Pre-Cordillera and the Brazilian shield—continued into the Pleistocene—the wonderful development of vertebrate life in the evolutionary region of Patagonia and Tierra del Fuego: the gigantic, rhythmic compressions on the west resulting in the upheaval of the Andes with the eruption of trachytes, andesitic basalts, and tuffs, and the injection along its length of huge bodies of granite and granodiorite during the latest Cretaceous and much of the Tertiary. Well-marked is the correlation between the several fairly-distinct diastrophic phases of the west and the minor vertical movements of the east with advance or retreat of the ocean.

Throughout the work the influence of tectonic movements in determining the areas of erosion and sedimentation is skilfully demonstrated, with insistence that folded mountain chains do not end at the borders of Argentina or even at the margins of the present continent, and the several parts played by the south-westward trending " Brasilides " (Silurian), the north-westward directed " Gondwanides " (Permo-Triassic), the meridional " Andine " foldings (Cretaceo-Tertiary) and the curve of the latter to the east in the " Antarctandes ", are clearly set forth in Section IV. The Orkneys and South Georgia are regarded by the author as isolated fragments torn off from the ancient Antarctic massif.

The factors that went to shape South America and the various hypotheses regarding former continental extension are discussed with restraint, the author showing a distinct leaning towards the Displacement Hypothesis. Weight is put upon the evidence afforded by the Mid-Atlantic Ridge. The Atlantic Ocean is regarded as having been developed in the main during late Cretaceous and early Tertiary times.

The chapter on Economic Geology deals with (1) the various metalliferous deposits that are mainly of pneumatolytic or hydrothermal origin and connected with the Palaeozoic granites or the Tertiary quartz-porphyries; (2) the recent petroleum developments in Salta and Jujuy (Devonian) and Neuquen (Senonian); (3) the important artesian resources, largely from the writings of Stappenbeck, and (4) the numerous thermal springs, many of which are of therapeutic value.

All through his work Dr. Windhausen shows considerable discrimination in his handling of debatable matters, as for example in discussing the age of the " Horizonte Calcareo-dolomitico " of the north-western region. The volume is extremely well arranged and printed; the plates are many and illuminating, while there is a wealth of text-figures including some palaeographical restorations, not to mention stratigraphical tables. A good bibliography is attached to each chapter, while there are full general indices. The coloured map of the Republic includes the adjoining territories of Chile and Uruguay, is on a scale of one to eight million, and is clear, though rather generalized in places. While the absence of all place-names makes it easy to read, the reviewer considers that the insertion of the names of the more important towns and natural features would have been of inestimable advantage, particularly to those who do not have an intimate knowledge of the country. In a work so complete and so packed with valuable information, that justice cannot be done to it in a short review, one is rather surprised to find no account of the soils of Argentina in view of the importance of agriculture in that land.

For long now the only comprehensive accounts of the geology and structure of this part of South America have had to be gleaned from Suess' monumental work, wherefore geologists the world over should be grateful to Dr. Windhausen for putting into accessible form so fine an account of a part of the Southern Hemisphere with most uncommon attractions, and it is to be hoped that the fact of it being written in Spanish will not deter them from studying this valuable and instructive work.

A. L. du Toit.

OUTLINE OF THE GEOLOGY AND PETROLOGY OF SURINAM (DUTCH GUIANA). By R. IJZERMAN. Pp. xv + 519, with 48 plates, 63 text-figures, and 4 maps. Utrecht: Kemink en Zoon. n.d.

THIS well-printed and splendidly illustrated quarto volume gives an account of the author's investigations of the geology of the colony of Surinam, commonly known in this country as Dutch Guiana.

In broad outline Surinam comprises a narrow coastal strip of Pleistocene alluvium, bordering a mass of igneous and metamorphic rocks, apparently the usual type of fundamental complex. There is also known one "Table Mountain" of flat-lying sandstone, obviously the equivalent of the Roraima formation of British Guiana. In this memoir the petrography of the old rocks is described in great detail, with many fine illustrations. The igneous rocks show a wide range of types from basic to acid, both plutonic and hypabyssal, of a distinctly calc-alkaline character. Some of the granitic rocks are much foliated (orthogneisses), while there is a great variety of paragneisses and schists, with greywacke, phyllites, and slates. There is some gold-washing in creeks, and boulders of cinnabar have been discovered. Otherwise little appears to be known as to economic minerals.

MINERALS IN MODERN INDUSTRY. By WALTER H. VOSKUIL. New York: John Wiley & Sons, 1930. Price 18*s.* 6*d.*

THE author states in the preface that this book "aims to present the fundamental economic facts and characteristics relating to the mineral industry. The technical phases, mining, ore-dressing, and metallurgy are discussed in the many works available on these subjects, and are treated here only to an extent that is considered essential in understanding the economic aspects of the production of minerals and metals ".

In spite of the scarcity of scientific information this volume contains interesting matter, particularly on the coal, oil, and natural-gas industries, these subjects filling nearly half the book. It deals chiefly with the United States. There is also an interesting chapter on the alloying metals of steel, in which, however, molybdite, instead of molybdenite, is given as the ore of molybdenum. In the chapter on natural gas there is no mention of helium.

In reading a compilation such as this the reviewer can only turn to regions with which he is familiar as a test of accuracy in the whole, and the test when applied to this volume leaves some misgiving. Thus on p. 253 the author appears to think that the Straits Settlements are a Dutch possession; and a paragraph on p. 255 on export tariffs is marred by an important omission. It is stated that the duty on exported tin-ore in British Malaya is 73 per cent with an additional duty of $30, Straits, per picul on ore exported to be smelted outside the British Empire. The export duty on such tin-ore is, in fact, 72 per cent of the duty on metallic tin, plus $30 a picul (16.8 piculs equal 1 long ton). The author states correctly that this prohibitive duty of $30 a picul was designed to frustrate an attempt to obtain complete control of Malayan tin.

In the final chapter the author writes: " The world's store of minerals need cause no immediate concern or necessitate drastic measures of economy or conservation."

J. B. S.

SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN, 1930. Pt. 1, 2*s*.; Pt. 2, 2*s*.; Pt. 3, 2*s*.

FOLLOWING the much appreciated custom of recent years, the *Summary of Progress* is again published in three separate parts, the first dealing more particularly with the routine work of the Survey, the other two parts containing a series of short memoirs on various topics of present-day interest.

It is good news that the Scottish Branch have been able to return to the primary Survey of the Highlands, for there is very much of scientific interest to be gained from such work, and there was a fear lest we should fall behind our colleagues in America and on the Continent in carrying out work of this nature. The publication of the *Ardnamurchan Memoir* adds another volume to the fine series dealing with the history of Tertiary Vulcanicity in these islands. The revision of the Coal Fields appears to be completed for the most part, and the revised maps with their accompanying Memoirs are in process of publication.

In the Shetlands, Dr. Read has completed the survey of Unst, the metamorphic rocks of which show many features of considerable interest, as his report clearly indicates.

In parts 2 and 3 the Survey has wisely made use of the knowledge of experts outside the official staff, so that there is a contribution by Dr. Stanley Smith on "Some Upper Carboniferous Corals from South Wales", and Professor Trueman joins with Dr. Wray in a further contribution showing the value of the non-marine Lamellibranchs as zonal indices in the Upper Carboniferous of Yorkshire. Others of these short Memoirs of special interest are those of Mr. Kennedy on the "Parent Magma of the British Tertiary Province", and Dr. Crookall's "Correlation of the British and French Upper Coal Measures".

G. L. E.

THE GEOLOGY OF THE WHITEHAVEN AND WORKINGTON DISTRICT (Expl. Sheet 28.) By T. EASTWOOD, E. E. L. DIXON, S. E. HOLLINGWORTH, and B. SMITH. *Mem. Geol. Survey.* pp. xi + 304, with 8 plates and 27 text-figures. 1931. Price 6*s*.

THE appearance of this Memoir has been awaited with great interest by Lake District geologists. It is true that the area actually covered by Sheet 28 barely touches the western fringe of the Lake District, including only the extreme western end of Ennerdale Water, but it allows of a discussion of a considerable tract of Skiddaw Slates and the western end of the Buttermere–Ennerdale granophyre. The greater part of the map is, of course, occupied by Carboniferous and New Red rocks, including a large part of the Cumberland coalfield and the great haematite mining region. In point of fact, about half the sheet is sea, but, of course, as is well known, coal is mined for several miles beyond the shore-line off Whitehaven. It is obvious, therefore, that there is plenty of scope for the reviewer. It is not intended on this occasion to deal with the Carboniferous and later rocks, interesting as they are, or with the striking glacial phenomena of the area, which have been so well described in previous publications (*Summary of Progress* of the Geological Survey for various recent years). The Skiddaw Slates and the granophyre provide quite sufficient material for a review. Reference may be made, however, to a pleasing inclination, apparently almost involuntary, to adopt the term "New Red Sandstone" without bothering about distinctions between Permian and Trias, which in this region at any rate are obviously perfectly futile.

The dominant structural feature of the older rocks is the south-westerly continuation of the Skiddaw anticlinorium, which here consists of three principal anticlines, with a highly complicated system of small-scale folding of all types as a subsidiary feature; nevertheless for some reason which is not at all obvious, at any rate to the present writer, cleavage is not much developed, in contrast with the Skiddaw district.

The classification of the pre-Borrowdale rocks finally adopted is delightfully simple. It is just this :—

Latterbarrow Sandstone.
Mosser Slates with Watch Hill Grits in upper part.
Loweswater Flags and Blakefell Mudstones.

The Kirkstile Slates of the 1924 classification are now considered to be merely a local syncline of Mosser Slates, while the Loweswater Flags and Blakefell Mudstones are facies variants of the same age. In the memoir a reference is made to a suggestion by myself that the Watch Hill Grits might be pre-Cambrian. This was based entirely on the lithological resemblance between certain coarse grits north of Skiddaw and the Ingleton grits, which I then correlated with the Upper Longmyndian, as I still continue to do. I had of course, no stratigraphical evidence at all in support of this rash statement. At any rate it is clear that these old grits contain relics of some still more ancient and very interesting rocks, of which we have otherwise no present knowledge.

The palaeontology of the Skiddaw Slates is here discussed at some length, material being borrowed from the adjoining sheet to the east. The upshot of it all seems to be that there is no certain evidence for the existence of any Cambrian (Tremadoc) graptolite zones, and that the ranges of certain species of graptolites in Cumberland are not the same as in Wales, while there is a much closer correspondence with Quebec.

With regard to the granophyre this review from here onwards must of necessity take on a personal aspect. In the early days of my geological career I published a petrographical study of this great intrusion, and it is comforting to find that so far as descriptive petrography is concerned, most of my conclusions are accepted by the Survey. But as to the form of the intrusion, I wish to state, without reservation, that I made a serious blunder. I described this intrusion as a cedar-tree laccolith, in spite of the fact that I toiled up and down thousands of feet of the vertical contacts so graphically described in this memoir, while I was totally unable to appreciate the meaning of the flat roofs shown in the illustrations to the same. My only excuse can be that I paid far too much attention to the old one-inch map, which shows lenticular outcrops of granophyre, especially in the country down towards the foot of Wastwater, and further that at the time when my work was done the petrological atmosphere was dominated by the recent publication of Dr. Harker's great work on Skye. It is an interesting example of the influence of a fixed idea. I have no doubt whatever that the explanation of this intrusion as a flat-roofed stock is perfectly correct.

The only other point to be dealt with here is the age of the granophyre. It is somewhat surprising to find that, on apparently good evidence, this is now regarded as Caledonian. While firmly believing that all the other Lake District granites are of this age, I had always regarded the Ennerdale granophyre as being the acid differentiate of the Borrowdales, intruded in semi-plutonic form. In this connection the findings of the Survey with regard to the age of the Carrock Fell mass, which shows many similar features, will be intensely interesting. It is to be hoped that their publication will not be long delayed.

R. H. RASTALL.

CORRESPONDENCE.

THE MECHANICS OF MOUNTAINS.

SIR,—In the October number of the GEOLOGICAL MAGAZINE, Dr. Harold Jeffreys independently develops a superficial-slip explanation for the far-travelled nappes so often encountered in mountain chains. He will be pleased to learn that his hypothesis has been repeatedly applied by leading alpinists. Let us take, for instance, the interpretation of the Prealps, as stated in detail by Schardt in 1898. This author considered that the Prealpine nappes had performed most of their journey after they had parted company with their roots (" Les régions exotiques du versant nord des Alpes suisses," *Bull. Soc. vaudoise des Sci. nat.*, xxxiv, 211–14). One may paraphrase his conclusion by comparing the Prealpine klippen with a Hawaiian surf-rider, mounted on his board, and skilfully gliding down the forward slope of an advancing wave. Substantially the same view was adopted by Argand in 1916, as English readers may readily appreciate on consulting Argand's diagrams of that date reproduced in Collet's *Structure of the Alps*, p. 20. From the Prealpine klippen of the western Alps one's thoughts naturally turn to the Window of the Hohe Tauern farther east. Here Suess—like most of us a convinced believer in the reality of the window—has asserted : it " is too large to have been produced by erosion ", it has instead been forced open by a doming of the over-ridden foundation (*Face of the Earth,* iv, 171, 177). I do not myself follow Schardt, Argand, Suess, etc., when they speak in this fashion, but I do think it is important to keep their views clearly in sight, and I welcome Dr. Jeffreys' advocacy as likely to throw fresh light upon the subject.

E. B. BAILEY.

THE UNIVERSITY, GLASGOW.
11*th October*, 1931.

ANNOUNCEMENTS AND INQUIRIES.

AT the Centenary Meeting (1931) of the British Association for the Advancement of Science a committee was appointed to "examine and report upon Petrographic Classification and Nomenclature". Many outside the few appointed are interested in the problems that will be examined, and the Committee therefore invites readers of the GEOLOGICAL MAGAZINE to forward their views to the Secretary.

In the first place the Committee is attempting to evaluate the data available for establishing a sound classification of igneous rocks, and invites replies to the following questionnaire :—

(1) Do you agree that classification should be based upon chemical and physical characters (i.e. composition, both mineral and chemical, texture, and geological occurrence), as distinct from hypotheses of origin, etc.

(2) To what extent should the classification be based upon chemical composition as expressed in percentages of specific oxides ?

(3) How far should the classification be based upon facts of geographical distribution, i.e. upon the recognition of petrographical provinces ?

(4) Are you in favour of the separation of igneous rocks into three divisions, plutonic, hypabyssal (dyke rocks), and extrusive (lavas), following Rosenbusch and others ; or into two divisions only, following Zirkel, Iddings, and others ?

(5) If in favour of three divisions would you base the separation of the second from the third upon (*a*) texture, or upon (*b*) actual geological occurrence ?

(6) Should the naming of a rock be determined by the nature of the eruptive rocks with which it is associated, e.g. trachybasalts (trachydolerites of Rosenbusch) only distinguished from normal basalts by their association with other alkali-rocks.

(7) In aiming at a complete classification for general acceptance by petrographers, are you in favour of retaining time-honoured rock names, with meanings probably different in many cases from those originally given to the names ; or of introducing a new nomenclature ?

(8) Do you think that the requirements of field geologists should be allowed to influence the classification and nomenclature of rocks ; or should there be a simple classification with "field-names" for general use, and a more complete classification with more exact names for use in accurate petrography ?

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